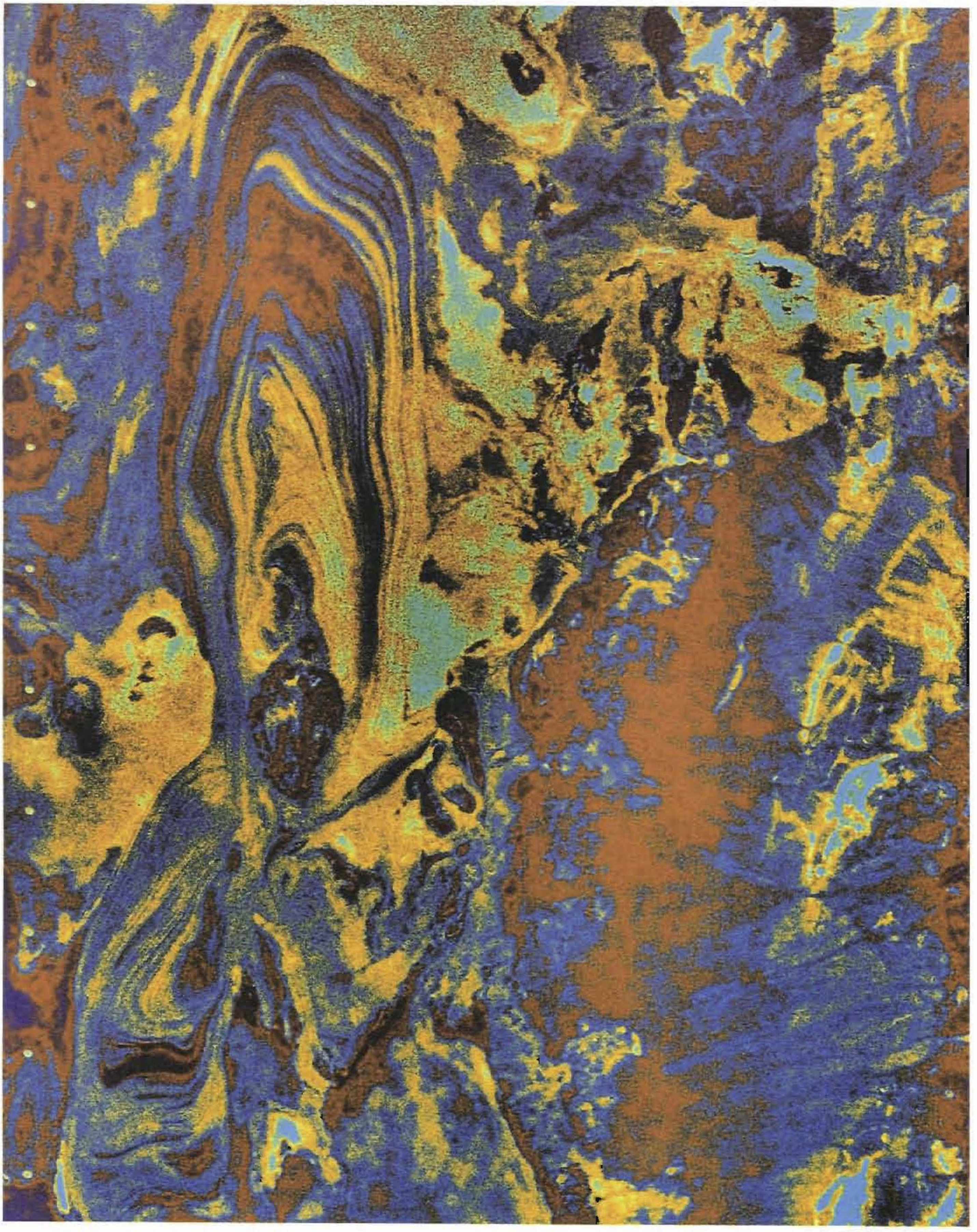
JET PROPULSION LABORATORY 1981 ANNUAL REPORT



CONTENTS

A description of work accomplished under a contract between the California Institute of Technology and the National Aeronautics and Space Administration for the period January 1 to December 31, 1981.

Cover The terrain of the Dasht-e-Kavīr (Great Salt Desert) in northern Iran is seen in this color-processed mosaic of images taken by JPL's Shuttle Imaging Radar-A (SIR-A), flown on NASA's space shuttle Columbia in November 1981 The marbled, swirling patterns are outcroppings of Miocene and Pliocene sediments Red and blue patterns are dry salt and clay deposits SIR-B, a JPL imaging radar, will fly aboard a shuttle in 1984.

JET PROPULSION LABORATORY
California Institute of Technology
Pasadena, California

In late summer of 1981 the world watched in fascination as the second Voyager made its marvelous flight through the Saturnian system, completing our exploration of those fascinating and complicated worlds. Voyager has been an example of how America's deep-space exploration earned the world's respect and admiration.

Galileo is well along its way to fruition and is a mission that should provide a hitherto-unknown depth of understanding of the solar system's major planet. New missions—the Infrared Astronomical Satellite, the Solar Mesosphere Explorer, and a variety of space shuttle experiments—are expanding the Laboratory's role in Earth-orbital missions.

But recent years have been especially hard on dreamers and visionaries like many of us at JPL. The future is always a bit scary to contemplate—because we can't see it clearly. We live in an extraordinary if unsettling time, and we at JPL live and work at the center of a well-spring of technological change. The setbacks over the last year were great. Our plans for new missions—to explore Venus, observe the Sun, encounter Halley's Comet—were swept away by the unprecedented trauma of cutbacks that affected every civilian federal program.

So we decided that JPL must look for new fields; and our space shuttle experiments have provided us with an auspicious entry into the shuttle-payload era. We are preparing several new shuttle experiments for flight. Furthermore, NASA is asking the Laboratory to contribute innovative ideas and concepts to NASA's main new thrust: a space station. I feel that JPL will continue to play an important supporting role for NASA.

But all the important new work for NASA is not likely to challenge us to our limits. JPL is known all over the world as the place whose unprecedented technical achievements, of the highest significance, are its principal product. If JPL is to be regarded in the same way in 1990, additional engineering challenges of the highest national priority must be added to our NASA commitments.

Therefore, in 1981 it became necessary to seek up to one-third of the Laboratory's new work from the Department of Defense, work to be carried out in a harmonious balance with a clear majority of NASA work. Under the new arrangement, JPL will remain a full-fledged member of the NASA family, while contributing significantly to the national defense.

In October 1981 formal endorsement of JPL's new direction was secured from Caltech and NASA. The Laboratory has moved out aggressively to develop a new suite of important Department of Defense tasks to which JPL can make significant contributions and which, at the same time, will help insure a healthy JPL. A Memorandum of Understanding was signed by JPL and the Air Force Space Division, heralding a new relationship with the military. Thus I feel that last fall we not only passed through the nadir point in terms of establishing JPL's future prospects, but that the Laboratory is well on its way to an exciting and challenging new era stretching through the rest of the 1980s.

Even as we work our way through the new arrangements with the Department of Defense and continue our work with NASA, the Laboratory must prepare for the 1990s. The Laboratory must persist in the most effective and significant energy research and development possible. This is especially important because it forces us to succeed in an arena where the government is the sponsor but not the customer. To be successful, the results of our government-sponsored activity must show up as progress in the private sector.

And JPL must continue to grow and evolve as an institution. The Laboratory must not grow older without constant efforts toward renewal, or we will lose our value and effectiveness. The very diversity of the challenges we accept helps to maintain the Laboratory's vitality.

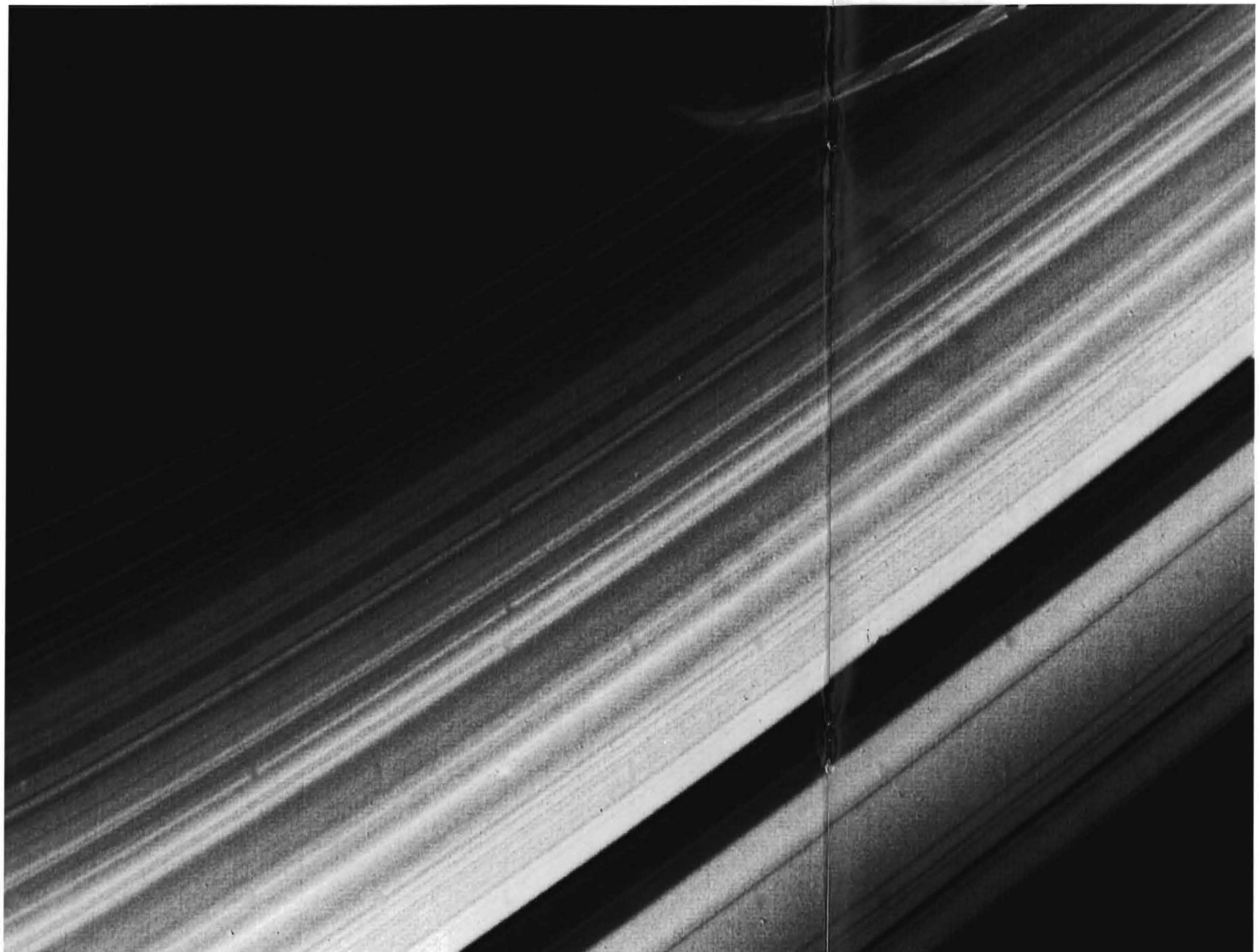
After more than 20 years of carrying out some of the most exciting and challenging engineering feats in the world, JPL is taking a new direction—transforming itself into a multi-mission laboratory tackling, with less central focus, a broad array of national requirements.

JPL is well on its way to an outstanding decade in the 1980s, following changing national priorities but keeping a preferred position in civilian space efforts, especially in deep-space exploration. If the current trends continue, there will be no better place to practice engineering or space science in the 1980s than JPL.

Bruce Murray

BRUCE MURRAY
Director

(Dr. Murray announced, in April 1982, that he would step down as director of the Laboratory later in the year. Caltech has formed a search committee to seek his replacement.)



The Cassini Division casts a bright band of light onto Saturn, visible at upper right.

Voyager 2 flew through the incredibly complex Saturnian system in the summer of 1981 and provided a wealth of information about the planet and its rings, satellites, and magnetic environment.

NASA and JPL closed the books on the Voyager primary mission, declaring it an unqualified success. The Voyagers, however, still have a long way to go: the Voyager Uranus Interstellar Mission will study Uranus and Neptune and probe for the edge of the solar system.

Development continues on the Galileo mission, a return to Jupiter using an orbiter and probe to conduct long-term studies of Jupiter and its satellites and to take the first samples of the giant planet's atmosphere.

Tracking and data acquisition by the Deep Space Network, which JPL operates for NASA, continued at a high level. Besides supporting Voyager at Saturn and Viking at Mars, the DSN continued to monitor the two planetary Pioneers as they reached record distances from Earth. And Pioneer 6, the oldest U.S. spacecraft still operating, continued to send data regarding the solar wind.

FLIGHT PROJECTS

Voyager

Voyager 2 encountered the planet Saturn in 1981, completing the Voyager Project's exploration of the Saturnian system and the primary Voyager mission. Both Voyager spacecraft were launched in the summer of 1977. Voyager 1's closest approach to Jupiter occurred on March 5, 1979, and Voyager 2's on July 9, 1979. Voyager 1 preceded its twin through the Saturnian system by nine months, with its closest approach occurring on November 12, 1980.

Both spacecraft performed nearly perfectly and, since the Voyager 1 science results were used in planning Voyager 2's activities, the information provided by the latter on Saturn's atmosphere, satellites, magnetosphere, and rings was of exceptional value. A temporary problem on Voyager 2's instrument scan platform, 100 minutes after closest approach to Saturn, resulted in the loss of some planned ring, satellite, and southern hemisphere observations.

Intensive observations of Saturn by Voyager 2 began on June 5, 1981. The spacecraft eventually returned pictures with higher resolution than those of Voyager 1. This was partly because pictures were being taken at closer range and partly because of improved camera sensitivity. Closest approach occurred on August 25, 1981, and encounter observations continued through September.

Voyager 2's scientific achievements contributed new knowledge of Saturn's magnetosphere, atmosphere, rings, and the ever-growing number of known satellites. Voyager 2 flew substantially deeper into the magnetosphere than did Voyager 1 and found no evidence for any significant asymmetry (other than the approximately 1° tilt of the rotation axis). During Voyager 2's passage, the magnetosphere apparently underwent a rapid expansion: it was about 70 percent larger at the time of Voyager 2's outbound magnetopause crossings than at the time of the spacecraft's inbound crossings. These observations are thought to be consistent with effects due to contact by Saturn's magnetosphere with the extended magnetic tail of Jupiter.

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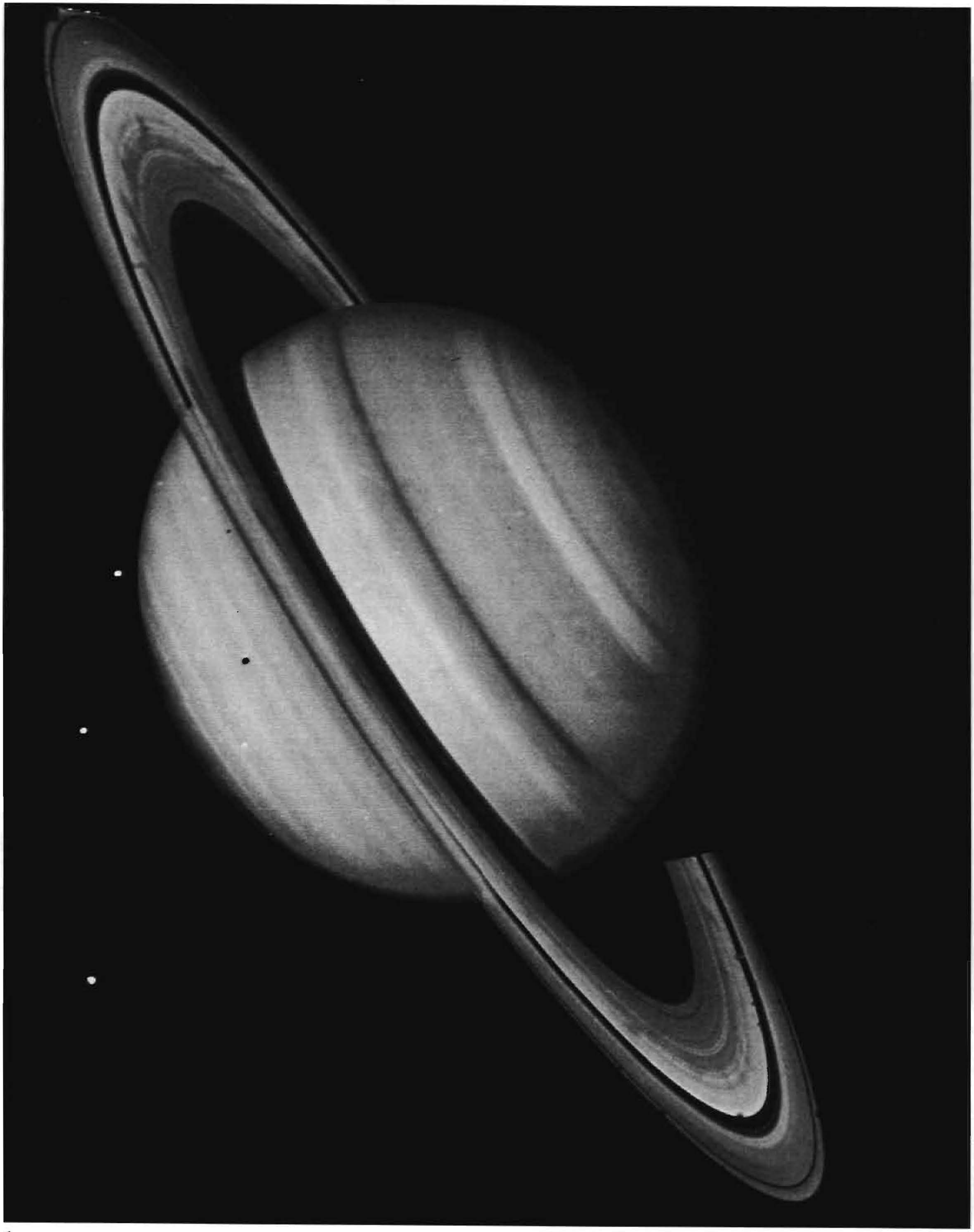


Saturn's atmosphere has a number of important similarities to Jupiter's. Wind velocities vary with nearly perfect symmetry from the equator to about both 75° north and 75° south latitude. Convective clouds form long-lived oval spots, very much like the similar features in Jupiter's atmosphere. The marked dominance of eastward-flowing jet streams on Saturn is an indication that the winds are not confined to the cloud layer, but are a deep-atmospheric phenomenon. The wind patterns may extend from north to south through the interior of the atmosphere in the form of differentially rotating, coaxial cylinders. The more muted cloud colors of Saturn, as compared with those of Jupiter, are probably a consequence of the colder temperatures and stronger cloud mixing in Saturn's atmosphere rather than of obscuration by overlying haze.

Voyager 2's photopolarimeter experiment, which measured changes in the intensity of starlight passing through Saturn's rings, obtained results of much higher resolution than was possible using Voyager 2's imaging cameras. These results revealed that the seemingly thousands of ringlets photographed by the cameras most likely in reality represent variations in the density of ring material, rather than separate rings.

Much of the fine-scale structure of the rings is constantly changing as gravitational interactions with some of Saturn's inner satellites generate density waves that spiral outward. Interaction with Mimas is strongest at the outer edge of the B-ring, where differences in the radial distance of that outer edge exceed 140 kilometers (85 miles).

Earth-based observations brought to 17 the number of Saturn's satellites known prior to Voyager 2's encounter. Voyager 2 provided photographs of all those satellites, and photographed 11 of them at a better resolution than was obtained by Voyager 1. Further analysis of the images has revealed four to six more tiny satellites.

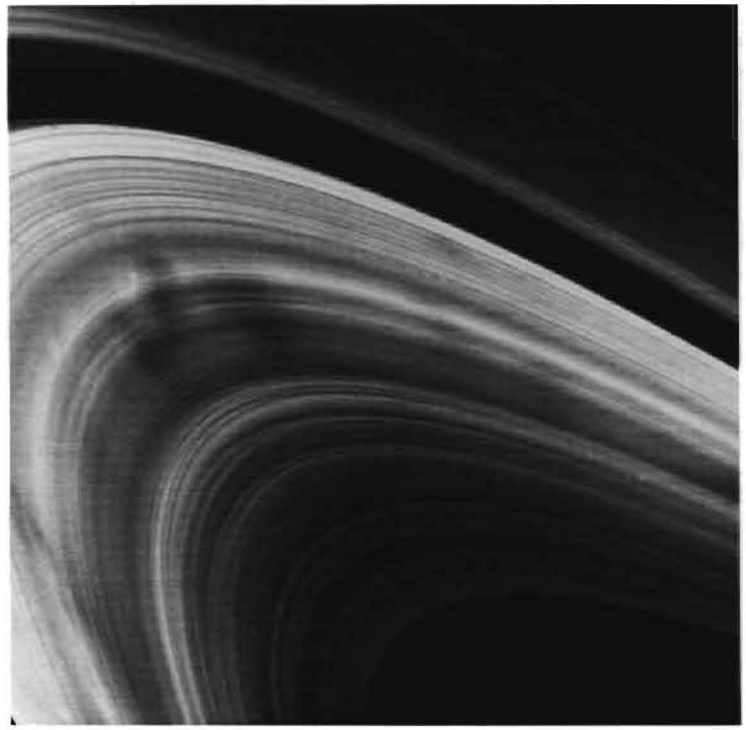
Phoebe, Saturn's outermost satellite, is roughly spherical, has a dark surface, and rotates about once in nine hours. It is the only one of Saturn's satellites known to be in nonsynchronous rotation.

The dark leading hemisphere of Iapetus is uniformly blanketed with dark material that reflects only one-tenth the light reflected by the satellite's trailing hemisphere.

Hyperion is irregular in shape and has a darker surface than most of the Saturnian satellites, while Tethys has a canyon, first seen by Voyager 1, that extends three-fourths of the way around Tethys' circumference. Tethys also has, on one face, a crater more than 350 kilometers (215 miles) in diameter.

By far the most active satellite surface seen in the Saturnian system is that of Enceladus. Tidal interaction with Dione seems the most likely source of energy for the apparently ongoing changes.

NASA has declared the Voyager mission a complete success. Voyagers 1 and 2 have accomplished all their planned objectives at Jupiter and Saturn. The scientific data gleaned from the four encounters has exceeded all expectations in terms of both volume and significance. The two spacecraft are expected to continue providing important information on the nature of the solar system for years to come.



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A. This photograph was taken on August 4 at a distance of 24.8 million kilometers (15.4 million miles). Only small variations in Saturn's intrinsic color are evident.

B. The "spoke" features of the B-ring are very clear in this Voyager 2 photograph. The sharp, narrow appearance of the spokes suggests short formation times. Although no detailed theory of formation has been agreed upon, scientists believe electromagnetic forces may be responsible for these features.

C. Special processing has brought out surface detail in this Voyager 2 image of Tethys that focuses on the satellite's large crater. The crater has been flattened by subsidence of the surface and no longer shows the deep bowl shape characteristic of smaller, fresh craters in hard ice or rock.

A new mission has been established for the spacecraft—the Voyager Uranus Interstellar Mission. Voyager 2 is on course for an encounter with Uranus in January 1986 and with Neptune in August 1989. Voyager 1 is en route out of the solar system on a course 35 degrees above the plane of the ecliptic.

Galileo

Galileo is a NASA flight project to orbit the planet Jupiter and release an instrumented probe into the planet's atmosphere. The spacecraft will be launched in 1985 from the Space Shuttle.

The year 1981 was eventful for Project Galileo. A delta-vega (which stands for changing a spacecraft's velocity by using an Earth gravity assist) trajectory was chosen for the spacecraft. This trajectory will delay Galileo's arrival at Jupiter until late 1989 or early 1990. The choice, dictated by the need to use NASA's two-stage inertial upper stage, will force a decrease in the number of orbits of Jupiter during the spacecraft's 20-month lifetime at Jupiter. Some redesign of the Orbiter was undertaken to reintegrate the Probe and Orbiter and to adapt the spacecraft to the 1985 mission.

System designs for the Probe and Orbiter were completed and critical design reviews were held in November. In addition, science and mission requirements that fully preserved the original science objectives were established and documented for the new 1985 mission.

Fabrication of flight hardware began on nearly all subsystems and has been completed in some instances. JPL has overall responsibility for Galileo, is designing and building the Orbiter, and will control the flight. NASA's Ames Research Center is responsible for development of the Galileo Probe, which is being built by Hughes Aircraft Company. The Department of Energy is providing the radioisotope thermoelectric generators, and BMFT in West Germany is responsible for the retropropulsion module.

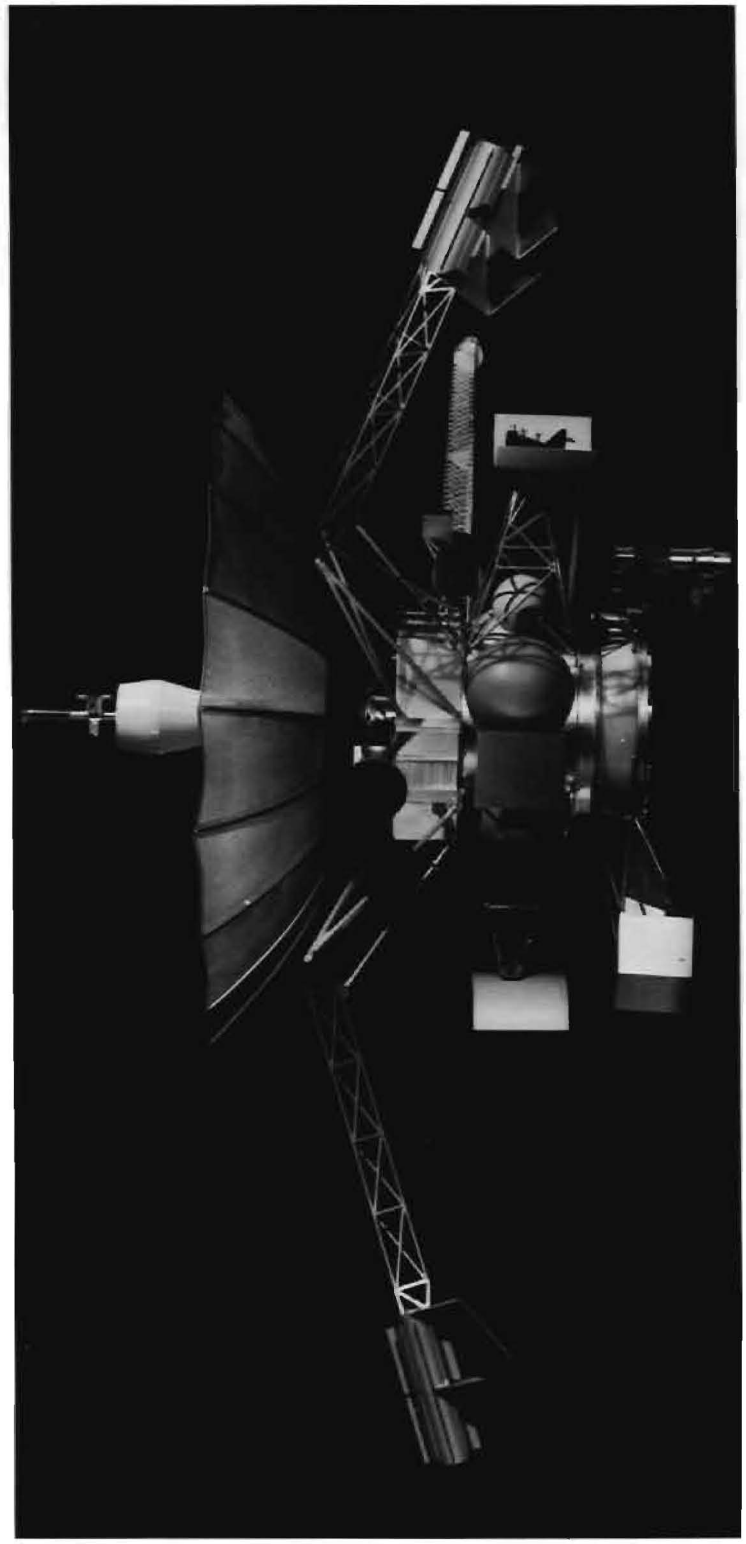
International Solar Polar Mission

The International Solar Polar Mission (ISPM), authorized by Congress in fiscal year 1979, is a continuing cooperative program between the European Space Agency (ESA) and NASA.

As a result of decisions by NASA in late 1981, ISPM has been reduced from a two-spacecraft mission to a single-spacecraft mission by the elimination of the NASA spacecraft. The remaining spacecraft's launch has been delayed from April 1985 to May 1986.

The European Space Agency is responsible for providing the spacecraft and has contracted with the Dornier System in the Federal Republic of Germany for the spacecraft's development. Subsystems for the spacecraft are being provided under contract to Dornier by industrial organizations in the various ESA member states. Separately, individual member states are providing a number of the instruments to be flown aboard the ESA spacecraft.

JPL, NASA's project manager for ISPM, is responsible for managing the development of five of the scientific instruments. A major portion of another instrument is being developed at JPL.



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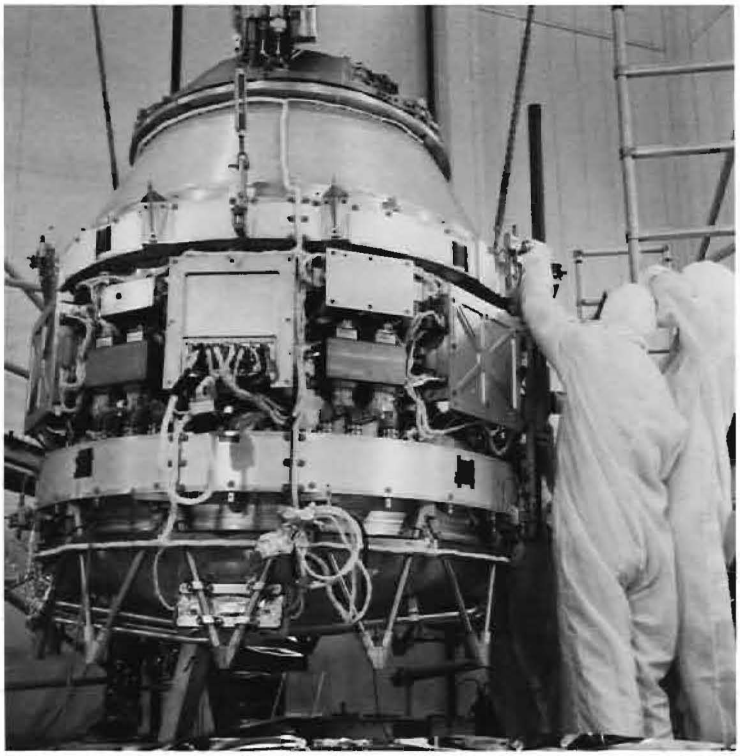

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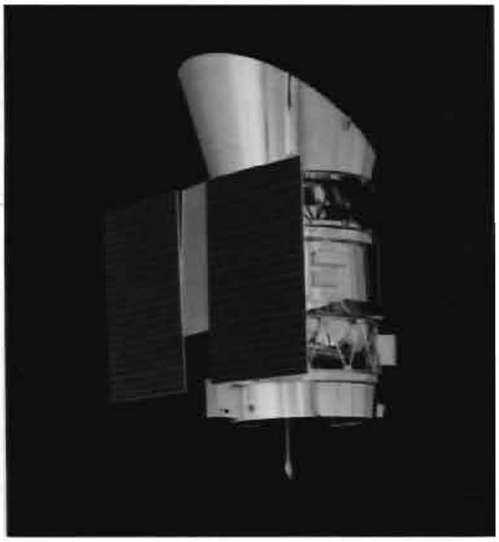

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A. The Galileo Orbiter will photograph Jupiter's cloud tops and Galilean satellites and will monitor the Probe when it penetrates the Jovian atmosphere.

B. Testing the mated telescope and spacecraft under space-environment conditions is one of the vital last steps in preparing the IRAS satellite for launch.

C. This model of IRAS shows the satellite's two power-generating solar panels.

JPL is also responsible for mission design, tracking, flight operations, and data records preparation and distribution. Other JPL assistance to ESA and to the experimenters includes supplying radiation-hardened parts and miscellaneous other hardware, as well as test facilities and analyses. JPL is also coordinating with the Department of Energy for the development and delivery of a radioisotope thermoelectric generator to power the ESA spacecraft, and with other NASA centers responsible for launching the ESA spacecraft.

Infrared Astronomical Satellite

The Infrared Astronomical Satellite (IRAS), which is planned for launch in late 1982, will carry a cryogenically cooled infrared telescope with an aperture of 57 centimeters (about 22 inches) into a near-polar orbit with an altitude of 900 kilometers (560 miles).

Before its cryogenic coolant is exhausted, about one year after launch, the satellite will have surveyed the sky at infrared wavelengths not observable from Earth's surface (because those wavelengths are blocked by the atmosphere) to produce an infrared sky map and a catalog that may contain several hundred thousand new infrared sources. IRAS will contribute to the answering of such astronomical questions as the origin, constitution, and replenishment of interstellar and circumstellar matter and the formation of molecular clouds and stars. IRAS will also provide insight into the problem of energy balance in ionized hydrogen regions, normal galaxies, extragalactic sources, and quasistellar objects. IRAS should permit scientists to study infrared objects throughout the Milky Way Galaxy.

JPL is responsible for project management and the design and operation of the science data analysis facilities. Ames Research Center was responsible for developing the telescope system. The spacecraft was built in the Netherlands, and the mission-control facilities will be located in England. During the mission, scientists from the United States, the United Kingdom, and the Netherlands will gather at JPL to interpret the data.

Problems have been encountered in the equipment that operates at cryogenic temperatures. After initial difficulties, the optical subsystem with its beryllium primary mirror was completed. The focal-plane infrared detector and preamplifier assembly have been redesigned at JPL to provide an operating temperature of about 700 kelvins (800° Fahrenheit) for the preamplifier. The detectors operate at approximately 2.8 kelvins (−454° Fahrenheit) while the entire superfluid helium cryostat operates at 2.2 kelvins (−455° Fahrenheit). Initial assembly and testing of the telescope system and its cryogenics, optics, and electronics were completed using a prototype focal-plane assembly. The telescope was then integrated with the spacecraft in the Netherlands. The satellite was shipped to JPL for assembly and environmental testing. In addition, modifications to the cryogenic valves and plumbing were made at JPL to resolve problems found during system testing.

Viking

The Thomas A. Mutch Memorial Station (Viking Lander 1) has continued operating for another year on Mars.

At the end of 1981, the spacecraft had been operating for more than 1,900 Martian days over three Martian years. This continual operation has permitted meteorological observations for almost three complete annual cycles. During 1981, 22 transmissions from the station were received. Each provided the meteorological data from which Martian weather patterns are being developed through analyses at the University of Washington. This is the only long-term climatic data being obtained from any planet beside Earth.

Imaging data has provided a further glimpse of the now-familiar terrain in the vicinity of Viking Lander 1. The opacity of the pictures is a clue to the existence of dust storms. One storm was observed by Viking Lander 1 on June 14, 1981.

Each transmission is a two-way communication that allows ranging and Doppler measurements. The Mars ephemeris is being improved by the data, and relativity studies are continuing.

It is planned to operate the Mutch Station into the 1990s.

Wide-Field and Planetary Camera

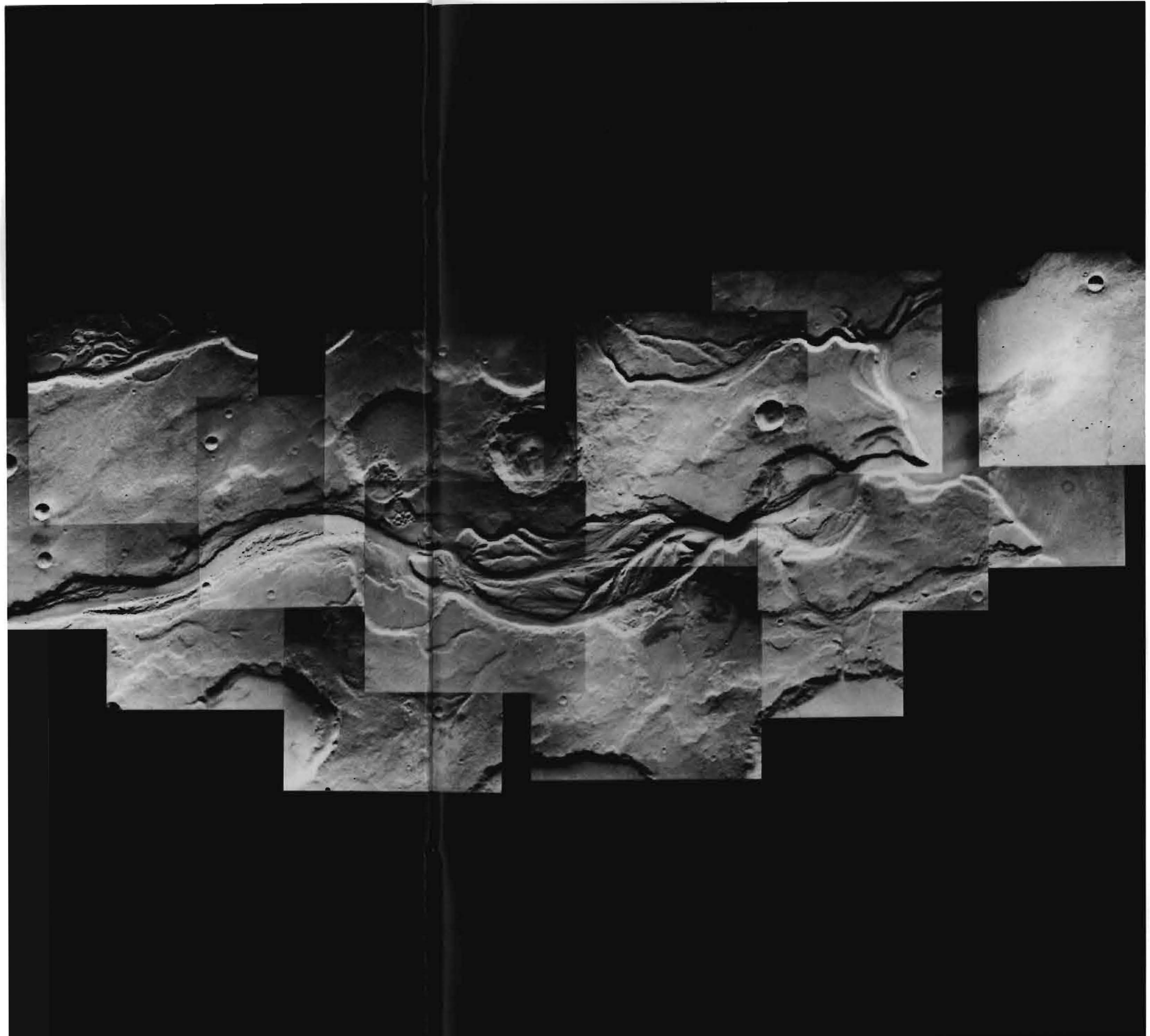
The Space Telescope, scheduled for launch from the Space Shuttle in 1985, will carry the Wide-Field and Planetary Camera designed and being built by JPL and Caltech.

Objects to be studied range in distance from planets within our own solar system to nearby stars and beyond—to galaxies and quasars in the farthest reaches of the universe. Data obtained by the camera will help answer questions about the birth and evolution of the universe.

The camera system, in conjunction with the 230-centimeter (95-inch) telescope, will detect objects 100 times fainter than those visible from Earth-based telescopes, with 10 times greater resolution. The camera system, with a spectral response from 6,000 to 10,000 angstroms, will observe and detect sources radiating in wavelengths from the ultraviolet to the near-infrared portion of the spectrum.

Two cameras of different focal length share the instrument housing and electronics. The wide-field camera will be used to survey large areas of the sky, while the planetary camera will make high-resolution studies of individual objects like planets, galaxies, and stellar objects. The planetary camera's resolution is 0.043 arc seconds per picture element, which would allow the camera to see an object the size of a baseball from a distance of 200 miles.

Eight charge-coupled devices (CCD) will record observations made by the two cameras. An image acquired by either camera will be divided into four quadrants on four 800-by-800 picture-element CCDs. The four images may then be recombined into a mosaic by the ground systems.



This channel on Mars, probably formed by liquid water, was photographed by Viking Orbiter 1. The sinuous, braided character of the valley suggests water erosion that may have occurred during a warmer and wetter epoch of the Red Planet's ancient past. Viking Orbiter photographs of channels like this in the Mangala Vallis region have provided the best and most persuasive evidence that a large volume of water once flowed on the Martian surface, even though Mars is now a desert drier than the Sahara. While no liquid water has been found on Mars, water is frozen at and under the polar caps. In this photograph, streamlined erosional features can be seen on the channel floor. The channel mouth (right) and other areas seem to have been inundated by volcanic or other material blown by the wind.

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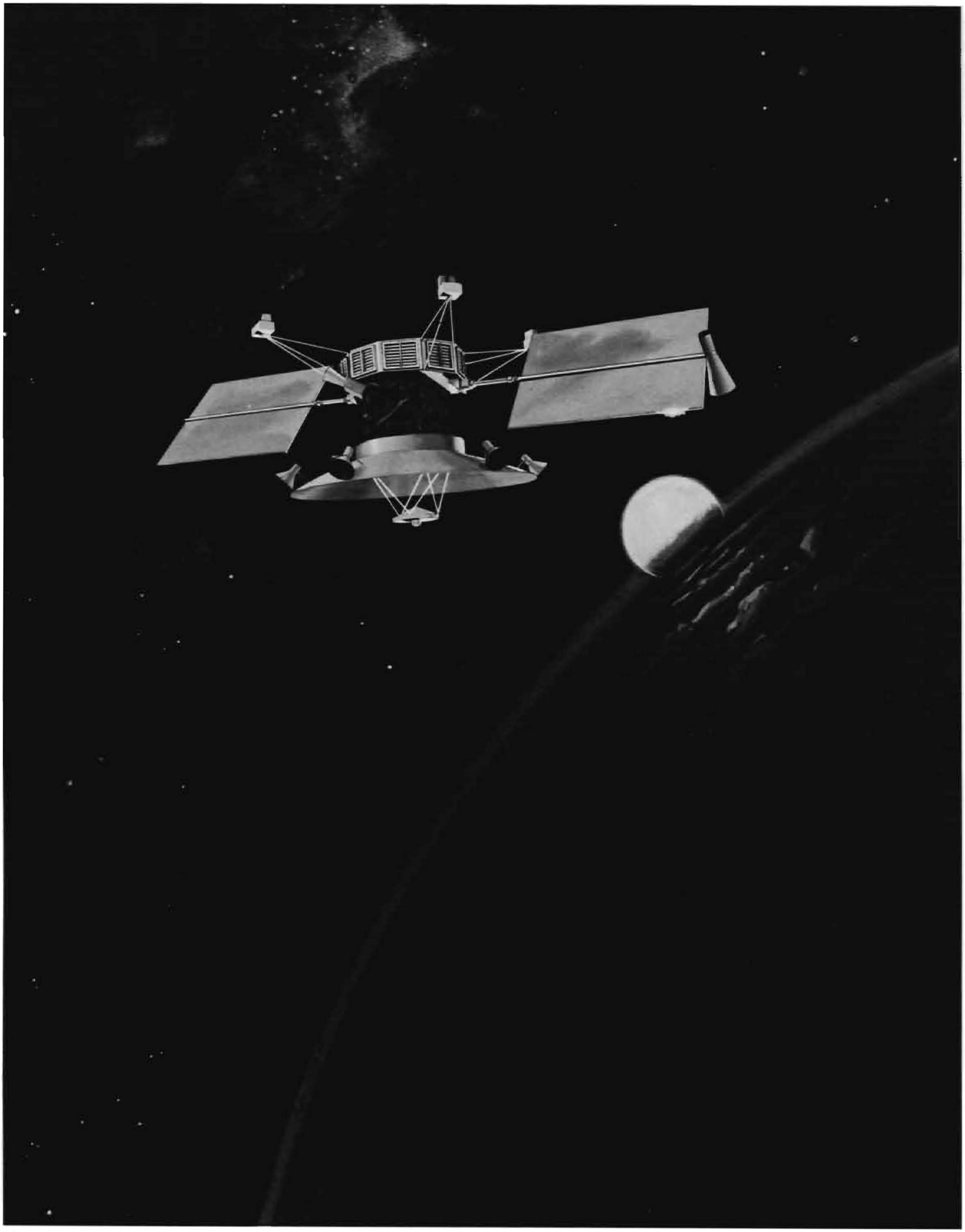

MISSION PLANNING

Planning continued on a variety of future mission candidates. Studies of a new class of Mariner spacecraft, Mark II, began at the Laboratory. The aim is to produce a spacecraft type that will provide a low-cost system for future planetary missions.

Halley Intercept Mission Study

The Halley Intercept Mission study investigated options for the exploration of Halley's Comet during its 1986 appearance.

The two basic missions investigated involved: first, a fly-through of the comet's coma (atmosphere of gases and dust) for *in situ* measurement of the gases and dust and close-up photography of the comet's nucleus; and, second, a fly-through of the comet's coma for collecting elemental samples of the gases and dust, to be returned to Earth for isotopic and elemental analysis. The high relative velocity (greater than 200,000 kilometers per hour) of the comet and spacecraft would vaporize solid particles striking the sample collection system, thereby providing elemental samples.

Several implementation approaches were investigated in an attempt to achieve the lowest practical cost for the desired mission options and their associated science return. Spacecraft options drawing primarily on the Voyager and Galileo inheritance were developed. In addition, industrial subsystem capabilities were surveyed for possible application, and the RCA Astro Electronics Division carried out an excellent study looking at the application of the Dynamic Explorer spacecraft to a low-cost elemental-sample-return mission.

Several Halley's Comet Mission options were implementable within the available schedule with costs ranging from approximately $150 million to $300 million, but none of the options was selected for a new start. The Halley Intercept Mission was terminated at the end of the year.

Venus Mapper

Studies of the Venus Orbiting Imaging Radar (VOIR) mission, leading toward acquisition of the radar and spacecraft contractors, continued in 1981. Late in 1981 the VOIR mission-start in fiscal year 1982 was cancelled. Planning began for a lower-cost mission, called the Venus Mapper, compatible with a new start in fiscal year 1984.

The prime mission objective is to map at least 70 percent of the planet's surface to a resolution of about 1 kilometer per line-pair. Radar images, altimetry data, and gravity data will provide an understanding of the processes that have shaped the surface of Earth's twin planet.

The contractor for the synthetic aperture radar was selected in November 1981. The spacecraft contractor selection is planned for 1982. JPL and the contractors are studying the Venus Mapper Mission as a new-start candidate for fiscal year 1984.

Extreme Ultraviolet Explorer

The Extreme Ultraviolet Explorer (EUVE) is a proposed Explorer-class project intended to conduct an all-sky survey at extreme ultraviolet wavelengths (100 to 1,000 angstroms).

EUV point sources would be observed in several wavelength bands, and their positions determined to a final accuracy of ±3 arc minutes. Diffuse sources and the cosmic EUV background would also be studied.

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A. Acquiring high-resolution radar images of Venus' surface through the planet's thick cloud cover will be possible with the Synthetic Aperture Radar. This artist's rendering shows the Sun rising behind the limb of Venus.

B. This photograph of Halley's Comet was taken on May 8, 1910. The elongated tail, composed of gas and dust blown away from the comet's head by the solar wind, may reach several million miles in length.

The science module would contain four extreme ultraviolet telescopes. One would point in the direction opposite the Sun. The other three would move with the spin axis and sweep the sky. Data would be taken only while the EUVE is in Earth's shadow.

The plan is to assemble, integrate, and test the spacecraft at JPL. The University of California, Berkeley, would develop and assemble the payload. A Shuttle launch is planned.

Advanced Studies and Mission Support

Advanced studies at JPL during 1981 covered a variety of subjects, from future Pioneer-class missions to providing interface support for the Space Shuttle program.

Starprobe Mission Study. The Starprobe mission, formerly called Solar Probe, would send a spacecraft on a mission close to the Sun. This mission continues to be the subject of preparatory studies at JPL. During the year, efforts were directed toward a lower-cost mission. Major cost sources are being identified in an effort to create a design that, while costing less, will nonetheless provide for a reasonable scientific return during a close approach to the Sun.

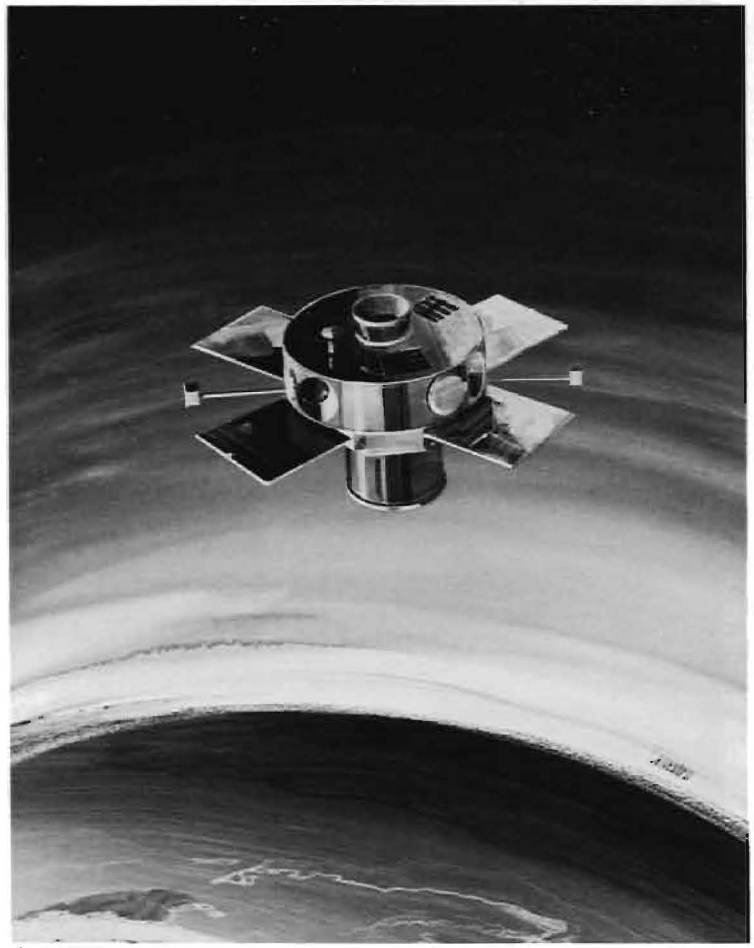
Mariner Mark II. The objective of the Mariner Mark II Project is to develop concepts that will permit space-exploration missions at considerably lower cost than past missions of equivalent complexity.

A challenging set of missions for the 1990s has been chosen for study. The set includes comet and asteroid rendezvous missions, as well as outer-planet flyby probe and orbiter missions. Among the latter possibilities is a Saturn orbiter that would perform repeated Titan flybys.

The mission set and the science objectives and typical payloads will serve to establish the requirements for Mariner Mark II spacecraft and ground system designs and for implementation approaches to achieve lower costs.

Methods being studied to substantially lower project costs include new implementation modes, reducing ground and flight system complexity, creating new design architecture in the spacecraft data system, taking appropriate advantage of new technologies, minimizing project-to-project modifications, and maximizing software and hardware inheritance.

The first project based on the Mariner Mark II Project would start in fiscal year 1986 or 1987, depending on the launch opportunity for the first mission. The plan is therefore based on a minimum four-year effort. That will permit in-depth cost-reduction studies and the preparation of detailed design and implementation guidelines for use by projects based on Mariner Mark II.



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A. The EUVE satellite will search the sky for extremely short-wavelength radiation in the spectral region between visible light and X-rays.

B. This mosaic of a Martian canyon is composed of photographs taken by Viking Orbiter 1 in May 1980 and processed early in 1982. The canyon is at least 800 kilometers (500 miles) in length, has an average width of 16 kilometers (10 miles), and is about 2 kilometers (1.3 miles) in depth. Its orientation is north-south. The sinuous course of the canyon suggests that it was formed by water erosion rather than tectonic activity.

B

Pioneer Missions. The name "Pioneer" in its present context covers planetary missions of modest scope that would make use of modifications of existing Earth-orbiting spacecraft. The goal of the mission concept is to perform worthwhile science investigations at minimum cost.

Cost minimization is achieved in two ways. The first is to use existing designs and hardware minimally modified for the mission. The second is to limit the science instrument payload to a very few or even a single instrument. Allied with those concepts is the simplification of mission operations to reduce demands on the spacecraft and to reduce operations team staffing.

Modifications to the spacecraft would be the minimum required to do a viable mission. The guiding principle is to design the best possible mission within the capability of the spacecraft, rather than picking the best possible mission and modifying the spacecraft to suit.

Several missions lend themselves well to that approach. A survey of the Martian magnetic field and its interaction with the solar environment is one. A study of the Martian atmosphere and its interaction with the surface and with space is another. Among the most interesting mission possibilities are detailed compositional surveys of the surfaces of the Moon and Mars. The missions would involve placing the spacecraft in low, circular, polar orbits that, over a period of about one year, would accumulate substantial observation time while covering the entire planet. The high-data-rate imaging systems that have characterized previous missions would be eliminated.

The most ambitious mission of the type being studied is a rendezvous with a near-Earth asteroid. This mission would be more demanding than orbital missions since it would require imaging as well as compositional data and more complex operations at the target. Nevertheless, it appears to be within the capabilities of the more advanced Earth satellites.

Solar Optical Telescope. The Solar Optical Telescope will be attached to the Space Shuttle's Instrument Pointing System and will provide high-resolution optical images of the Sun. The first flight is scheduled for 1986 and will have a duration of 14 days.

The telescope's primary mirror is 125 centimeters (49 inches) in diameter and can potentially obtain images of the Sun's surface with a resolution of 75 kilometers. Because it operates from 1,200 angstroms into the infrared, it can observe solar phenomena originating from the deeper photosphere and up through the chromosphere and corona.

JPL will supply charge-coupled device (CCD) camera heads and supporting electronics for the spectrograph, for which Dr. Alan Title of Lockheed Corporation is principal investigator. The camera heads will incorporate virtual-phase CCDs measuring 1,024 columns by 1,024 lines, and are under development by JPL at Texas Instruments, Inc. JPL began work on the project in March 1982 and will complete the manufacture of 10 flight camera heads and two electronic subsystems by the end of 1985.

Large Deployable Reflector. The Large Deployable Reflector (LDR) is planned to be a free-flying astronomical observatory that would be launched by the Space Shuttle. It would operate in the mode of the Space Telescope. NASA would provide the observatory to a user community, which in turn would provide some of the instruments. The telescope would be between 10 and 30 meters (33 and 100 feet) in diameter, with the lower limit dictated by previously defined science needs and the upper limit by practical technology and cost.

The operating wavelengths would be from 1 millimeter (1,000 microns) to 30 microns. Wavelengths longer than 1 millimeter (0.04 inch) can probably be detected better from the ground. The planned short-wavelength limit is a compromise between practical technology and the point at which smaller, cooled telescopes become the more sensitive type.

The LDR telescope would be a Cassegrain design of approximately f/1. The primary reflector would be made up of a number of close-packed hexagonal panels. Each panel would be actively controlled and would have three degrees of freedom, so that the overall optical figure of the primary reflector can be maintained to a small fraction of the shortest operating wavelength.

Space Transportation System Interface Office. The evolution of the Space Transportation System (STS) and its operational support-system elements is having significant technical and programmatic effects on JPL projects and programs.

To provide an understanding of those effects on JPL users and to plan for effective utilization of the STS, the JPL STS Interface Office provides support for the development of flight projects, for advanced mission studies, and for transition support for new flight projects.

SCIENCE

JPL maintains a strong research and technology program in the space sciences, for the support of past, present, and future missions. Continuing support for past missions is primarily in the area of data analysis, where scientists continue to reduce and analyze data from previous planetary missions. Support for present missions such as Voyager and Galileo, on the other hand, is in the form of project science support, science team membership, and overall science support. Future-mission support goes primarily to advanced studies that include possible low-cost planetary missions.

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A. Ice-coated Europa, one of Jupiter's Galilean satellites, is remarkably smooth, showing few craters. The uniformly bright terrain is mainly water ice. The chainlike ridges, a mere few hundred meters in elevation, offer the only topographic relief. These ridges could be the result of fresh ice being extruded through cracks in the surface. Europa's surface ice may be 100 kilometers (about 60 miles) thick and is perhaps underlain by rocky and metallic material.

B. This Apollo asteroid was discovered during the course of an ongoing survey of high-inclination asteroids.

Photochemistry of Venus and Earth

Interesting comparisons with Earth's atmospheric photochemistry have arisen from laboratory and modeling studies of the atmosphere of Venus.

A puzzle for planetary aeronomers is why CO_2 in the Venusian atmosphere is not significantly decomposed into CO and O_2 by sunlight. Evidence suggests that trace constituents in the atmosphere play a fundamental role. Furthermore, the mechanisms by which such processes operate bear a close analogy to those of trace species in Earth's own atmosphere. On Earth, similar problems have been the focus of considerable attention in connection with ozone-layer stability in the face of human activities including high-flying aircraft and chlorofluorocarbon emissions.

It appears that the photochemical reactions that control many critical atmospheric properties of Earth and Venus are identical, although there are differences in the net effect, arising from differences in bulk composition of the two atmospheres. Thus, whereas chlorine compounds in Earth's atmosphere are believed to have only the effect of ozone destruction (conversion to O_2), similar compounds may play a dual role in the Venusian atmosphere, in that they both enhance O_2 formation from species such as ozone and participate in O_2 removal through the oxidation of CO to CO_2. That effect would help explain the stability of CO_2 in the atmosphere of Venus.

Sulfur Dioxide Absorption Band on Europa

A team of JPL scientists has discovered an ultraviolet spectral absorption asymmetry on Jupiter's satellite Europa, which may provide a critical indicator of Jovian magnetospheric activity.

Using data from the International Ultraviolet Explorer (IUE), the team noticed a pronounced spectral absorption feature on one hemisphere of Europa. It has a spectral signature similar to sulfur dioxide gas.

Discovery of Apollo Asteroid 1981 VA

A new Apollo asteroid was discovered by JPL astronomers on November 3–4, 1981, using the 1.2-meter (47-inch) Palomar Schmidt telescope. The object, designated 1981 VA, was of 16.5 magnitude upon discovery, showing as a long, bright streak on the photographic plate as it moved away from Earth. It was photographed at a range of 43 million kilometers (27 million miles). Its orbit has an eccentricity of 0.74 and an inclination of 22 degrees. Perihelion is at 0.63 astronomical units (AU). Therefore, the asteroid crosses the orbits of both Earth and Venus. Its aphelion is at 4.3 AU, inside Jupiter's orbit.

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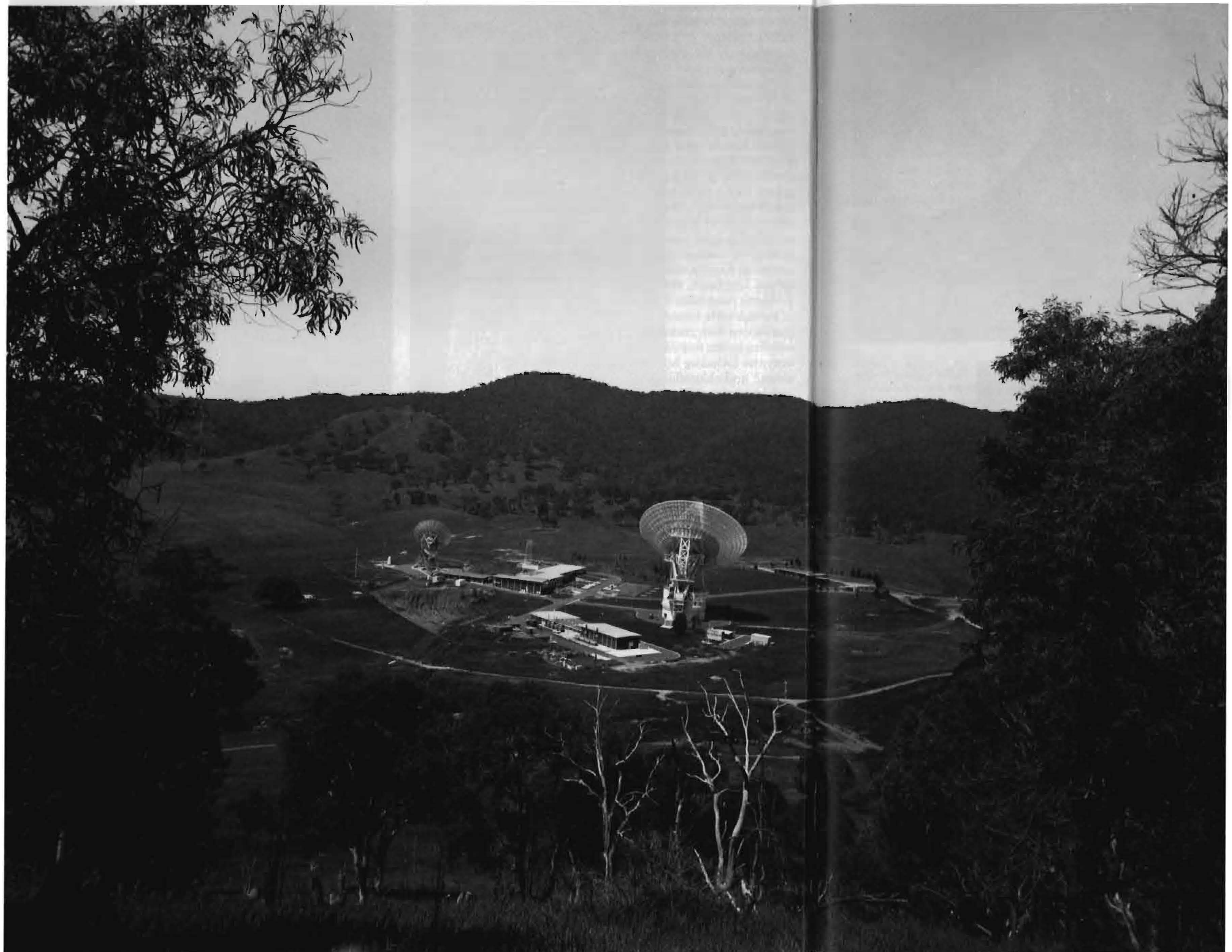

Deep Space Station (DSS) 43, located at Canberra, Australia.

The JPL Office of Telecommunications and Data Acquisition (TDA) manages the Deep Space Network (DSN) for NASA's Office of Space Tracking and Data Systems (OSTDS). The Network's primary role is to provide a worldwide system for communicating with spacecraft exploring the solar system. In the future, the same task will be performed by the Network for satellites in highly elliptical orbits as well as other Earth orbiters not supportable by NASA's Tracking and Data Relay Satellite System (TDRSS). The basic elements of the DSN are three deep-space communications complexes near Goldstone, California; Madrid, Spain; and Canberra, Australia; a ground communications facility; and a Network Operations Control Center at JPL. The TDA office also has responsibility for JPL radio science and supports radar and radio astronomy and geodesy uses of the DSN.

MISSION SUPPORT

Voyager

The major DSN operational support provided in 1981 was for Voyager 2's Saturn encounter. The Network provided command and telemetry data for the entire 116-day period. High-quality radio metric data, including very long baseline interferometry (VLBI) data, were generated for three trajectory-correction maneuvers during the encounter period. Three improvements at the Deep Space Stations were implemented between encounters, enabling better and more reliable support. The first was an automatic uplink tuning capability that made it easier to operationally deal with the narrow frequency range caused by a component failure on Voyager 2's receiver. The second improvement was the addition of a second X-band low-noise maser amplifier at each 64-meter site. The third was improvement of the gain of the Goldstone 34-meter S–X antenna.

Differential or delta VLBI was used for spacecraft navigation in a semioperational demonstration on Voyager 2 beginning in April 1981 and continuing beyond Saturn encounter. The technique uses antennas at all DSN sites, alternately observing the spacecraft and a natural radio source to precisely determine spacecraft angular position. The Voyager demonstration surpassed the original goal of 150 nanoradian angular velocity. Delta VLBI will be used to support Voyager 2 navigation to Uranus and beyond.

To support the near-encounter radio science, the multimission open-loop receivers and associated equipment were moved from Spain to Australia, and several improvements were made to the DSN Radio Science System. The radio-science data generated during the Saturn spacecraft occultation and ring-scattering was considerably improved over the Voyager 1 encounter.

The Network obtained about 12,000 high-quality pictures of Saturn, its rings, and its satellites from a communication distance of about 1 billion miles. During the encounter, 99.7 percent of the planned photos were received.

Pioneer Spacecraft

The DSN continued to support the Pioneer missions, which are managed by NASA's Ames Research Center. Throughout 1981 the Pioneer Venus spacecraft provided images of the cloud tops, investigated atmospheric physics, and measured electric fields and particles. These activities are expected to continue until 1992, when the spacecraft will enter the Venusian atmosphere.

Pioneer 6, a solar weather station in orbit between Earth and Venus, has exceeded 16 years of operation. It is the oldest spacecraft still functioning with operating science instruments. Pioneer 9, also a solar weather station in orbit between Earth and Venus, received substantial 34-meter support in late 1981, as its orbit brought it very close to Earth, an event that occurs about every four years.

Pioneers 10 and 11 have returned valuable science data from previously unexplored regions of space. Pioneer 10 is 26 astronomical units (3.8 billion kilometers, or almost 2.4 billion miles) from Earth, between the orbits of Uranus and Neptune. It will leave the solar system in 1987, but will maintain communications with Earth until 1991. Pioneer 11 is leaving the solar system more slowly but will maintain communications with Earth until 1992.

Pioneer 10 entered solar opposition in November and December 1981; and the opportunity was used in the continuing search for gravity waves.

Helios

Support of the remaining Helios spacecraft, a NASA–West German solar-exploration vehicle, continued in 1981. Helios 1 completed its 14th perihelion passage in December 1981, and the later solar-conjunction phase was intensively supported by the 64-meter subnetwork to generate data for several solar-corona radioscience experiments.

International Sun-Earth Explorer (ISEE)

The DSN supported studies and measurements at Goldstone using the ISEE-3 spacecraft to obtain accurate signal-level determinations. The purpose of the measurements was to determine whether the spacecraft could support a usable telemetry bit rate for a possible Halley Comet encounter by the ISEE-3, which has enough propulsion aboard to make the mission conceivable.

Giotto

NASA and JPL negotiated with the European Space Agency to support ESA's Giotto spacecraft mission to Halley's Comet. Encounter will occur in March 1986. Support will consist mainly of X-band telemetry at encounter and the generation of radio metric data throughout the flight, to navigate the spacecraft. It will be the first mission supported on a reimbursable basis by the DSN.

A

A. The DSS 13 antenna, which measures 26 meters (85 feet) in diameter, at the Goldstone Venus site. This site is used for the research and development of advanced antenna and receiver systems.

B. Located near Madrid, Spain, and measuring 34 meters (112 feet) in diameter, this antenna is part of NASA's Deep Space Network. Used to communicate with interplanetary spacecraft, the antenna is operated by the Spanish government and managed for NASA by the Jet Propulsion Laboratory.

DSN Implementation

DSN implementation in 1981 focused on three major efforts: 1) The Networks Consolidation Program (NCP); 2) The Mark IVA DSN Project; 3) The Voyager 2 Saturn encounter.

The Networks Consolidation Program merges several stations of the Ground Space Flight Tracking and Data Network, managed by Goddard Space Flight Center (GSFC), into the Deep Space Network. The program is in the detailed implementation phase. The consolidated Network will assume support for several spacecraft in highly elliptical Earth orbits. These spacecraft have up until now been supported by GSFC. In addition, the Network will continue to support JPL's traditional deep-space missions.

At the direction of NASA's OSTDS, emergency support for the Tracking and Data Relay Satellite was added to the Network's mission set. Addition of emergency support for the Space Transportation System will depend largely on results of experiments scheduled for the third Shuttle flight.

The Mark IVA DSN Project will configure the consolidated Network to support the Voyager 2 Uranus encounter and the Galileo Project, primarily through the use of larger arrays of both new and existing antennas to increase aperture. Improved centralized control of Network subsystems will enhance operations. Both the NCP and the Mark IVA DSN projects have progressed to the point of detailed functional design for several subsystems.

During 1981, an extensive analysis determined the potential benefits of building new 34-meter antennas rather than relocating and enlarging existing 26-meter antennas. Analysis showed significant cost savings could be achieved. The antennas would have better technical capability and still be less costly to operate and maintain.

A major upgrade of the JPL Central Communications Terminal before the Voyager 2 Saturn encounter simplified data routing and operations costs in the communications interface between the Deep Space Network and the project. The activity involved the reconfiguration of several computers and the delivery of four new major software programs to support the upgrade.

B

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A. *Upgrading the physical structure of DSN antennas permits their use at higher frequencies, thereby increasing antenna gain and improving telecommunications system performance.*

B. *The 64-meter (210-foot) antenna at Goldstone, California.*

C. *The Space Flight Operations Facility is the center for mission operations, where spacecraft tracking and scientific data are received from NASA's Deep Space Network and processed.*

Implementation of the Block I VLBI subsystem for the processing of data from two stations was completed in April 1981 and demonstrated during Voyager 2's Saturn encounter. The subsystem consists of a VAX 11/780 computer, an in-house-designed two-station 500-kilobit-per-second hardware correlator, and JPL-designed control and processing software. The subsystem uses VLBI and bandwidth synthesis techniques to determine station clock synchronization, polar motion, universal time, and delta differential one-way range for spacecraft navigation.

Galileo

In preparation for Galileo mission operations, three new capabilities will be implemented in the DSN. Wideband VLBI will give increased accuracy to the metric data used for navigation support. Navigation for the Galileo mission will use delta VLBI as the principal measurement technique. An improved transponder on the spacecraft and new operational equipment at the stations will reduce angular position error for a single 20-minute delta VLBI observation to less than 50 nanoradians. That translates to 25 kilometers (16 miles) at Jupiter.

In telemetry, a combiner has been designed for the 64-meter antennas to allow reception of linearly polarized radio-science signals through a circularly polarized feed without cross-polarization losses. The third innovation is real-time detection and display of the polarization angle of the linearly polarized signal.

TELECOMMUNICATION SCIENCE

Radio Astronomy

A number of significant radio-astronomy experiments were supported by the DSN during the past year. Observations of the energetic galactic object SS-433 continued, as did those of the twin quasar 0957+561A,B. Multiple quasar images are believed to be caused by an intervening galaxy refocusing rays from a single quasar. The K-band maser amplifier developed by JPL for the National Radio Astronomy Observatory was put into use at the Tidbinbilla station of the Australian complex. Its use as the low-noise amplifier in a K-band microwave spectroscope led to the discovery of two new water-vapor maser sources and six new ammonia sources. Other activities included observations of the Vega pulsar (PSR 0833), continued planetary radio astronomy, and participation in a multiobservatory nine-telescope VLBI observation of the superluminal quasars 3C273 and 3C245.

Radio Science

The Deep Space Network generated Doppler data for Pioneer 10 in an attempt to detect gravitational radiation passing through the solar system. The Einstein Theory of General Relativity predicts the existence of such radiation, but so far it has gone undetected. The record distance of Pioneer 10 makes it a good candidate for the detection of gravitational radiation from cosmic sources in the frequency region of 5×10^{-5} to 5×10^{-4} hertz.

Radar Astronomy

Radar observations of the asteroid Apollo, which passed within 8.4 million kilometers (5.2 million miles) of Earth in November 1980, resulted in an estimate of its radius at 600 meters (less than ½ mile) and its rotation period at three hours. X-band observations using the 64-meter antenna at Goldstone produced 48,000 individual spectra over a 14-hour period. Each spectrum had a bandwidth of almost 1,500 hertz and a resolution of better than 3 hertz.

Radar observations of Saturn's rings were made during 1981 when the ring plane was 6 degrees from edge-on. The normalized radar cross section did not drop appreciably with angle. The result, coupled with earlier data and computer scattering simulations, shows that the ring particles must be larger than the wavelength—on the order of a meter or larger. The hypothesis that the particles are made of ice fits the data, and the particles must also be irregular and jagged in shape.

Geodynamics Program

The JPL Geodynamics Program continued its extensive vector baseline determinations at a number of sites in Southern California.

Baseline changes are expected to shed some light on earthquake mechanisms. The primary instrumentation involves radio interferometry at microwave frequencies. The Laboratory has continued to upgrade its instruments and has completed the design of an operational unit.

The measurement program is closely allied with the Seismological Laboratory at Caltech, the U.S. Geological Survey at Menlo Park, California, and the National Geodetic Survey in Rockville, Maryland.

Another major technology development involves the use of single mobile radio terminals that receive signals from the satellites of the Global Positioning System. In addition to its application to geodesy, this activity has led to the demonstration of a precise ionospheric calibration technique. It also demonstrated, as part of the development, orbit determination to submeter accuracy. This has potential application to future Earth-orbiting missions that require precisely knowing spacecraft locations.

B

C

The Los Angeles Basin as seen by SIR-A, which can obtain images through cloud cover and at night.

In 1981 the Laboratory increased its involvement in Earth-orbital missions. The Solar Mesosphere Explorer, which is studying the dynamics of ozone in Earth's atmosphere, was launched on October 6, 1981, from Vandenberg Air Force Base. Two highly productive Earth-observing experiments flew on STS-2, the second flight of the space shuttle Columbia. A tentative launch schedule—November 1982—was set for the Infrared Astronomical Satellite.

ORBITAL FLIGHT PROJECTS AND EXPERIMENTS

Solar Mesosphere Explorer

The Solar Mesosphere Explorer was launched on a Delta launch vehicle on October 6, 1981, from the Western Test Range.

Mission objectives are to determine the nature and magnitude of changes in mesospheric ozone densities that are the result of changes in the solar ultraviolet flux, and to determine the relationship between ozone and solar flux, temperature, water vapor, nitrogen dioxide, and solar proton events.

The spacecraft systems are performing well within specifications, with the exception of the backup tape recorder.

The four limb-scanning science instruments are collecting ozone data using both the leading and trailing limbs. Solar irradiance between 1,200 and 3,000 angstroms is being measured by the fifth instrument. Full science data is being acquired using the remaining tape recorder 448 minutes each day.

The Mission Operations System is located at the University of Colorado and is staffed principally by university students.

The spacecraft was developed, assembled, and tested by the Ball Aerospace Systems Division, Boulder, Colorado. The science instruments were developed, assembled, and tested by the University of Colorado's Laboratory for Atmospheric and Space Physics (LASP). Integration, testing, and field operations were handled by Ball, and mission operations by LASP.

Shuttle Imaging Radar-A

JPL flew the Shuttle Imaging Radar-A (SIR-A) on the second Shuttle flight in November 1981. The instrument was part of the Shuttle's first scientific payload.

The SIR-A objective was to acquire radar images over a variety of geologic regions, in order to assess the capability of spaceborne imaging radar sensors to engage in geologic mapping.

Images were acquired around the world with a total coverage of 10 million square kilometers (3.9 million square miles). Preliminary analysis of the data is providing additional information on surface and near-surface structure, which in some regions is not available in the most recent geologic maps.

The success of SIR-A led to the approval of the follow-on program (SIR-B), which will use a more sophisticated instrument, to be flown on the Shuttle in 1984.

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Shuttle Multispectral Infrared Radiometer

The Shuttle Multispectral Infrared Radiometer (SMIRR) flew on the second flight of the Columbia, in November 1981. The instrument was designed to obtain measurements of Earth's reflectance in 10 spectral bands between 0.5 micrometers and 2.35 micrometers, for application to mineral-resources exploration.

In some cases, SMIRR surpassed field techniques in identifying minerals. For example, fine-grained clay minerals like montmorillonite and kaolinite, found in weathered rocks and widely distributed on Earth's surface, are so similar that they are distinguishable only through laboratory testing. The SMIRR experiment, however, from the Columbia's payload bay, 240 kilometers (150 miles) above Earth's surface, was able to individually recognize the two clays.

These results are important for the design of future high-spectral-resolution imaging systems and the demonstration of the value of narrow-band spectroscopy from orbit.

Ocean Topography Experiment

The Ocean Topography Experiment (TOPEX), proposed for the late 1980s, is an altimetric satellite mission designed to map the global ocean circulation in detail.

Currents and other features of ocean circulation create height differences on the ocean surface. The warm water of the Gulf Stream, for example, is higher than the colder water through which it flows. Ocean topography can be detected, in detail and on a global basis, only by using a satellite radar altimeter.

Improved knowledge of ocean circulation would contribute to an understanding of the relationship between the atmosphere and the ocean. TOPEX data would aid in the management of prime fishing grounds, help determine the movement of stable and radioactive pollutants, and provide improved surface-condition information, thereby assisting in the more efficient operation of commercial and naval vessels.

Mission plans call for TOPEX to be launched by the Space Shuttle in the late 1980s and for the satellite to measure the same area of ocean every 10 days over a three-to-five year period.

The mission is designed to coincide with the World Ocean Circulation Experiment, an international oceanographic effort planned for the late 1980s. TOPEX data would be combined with the latest information on ocean density and with theories of ocean dynamics to produce a more precise model of global ocean circulation.

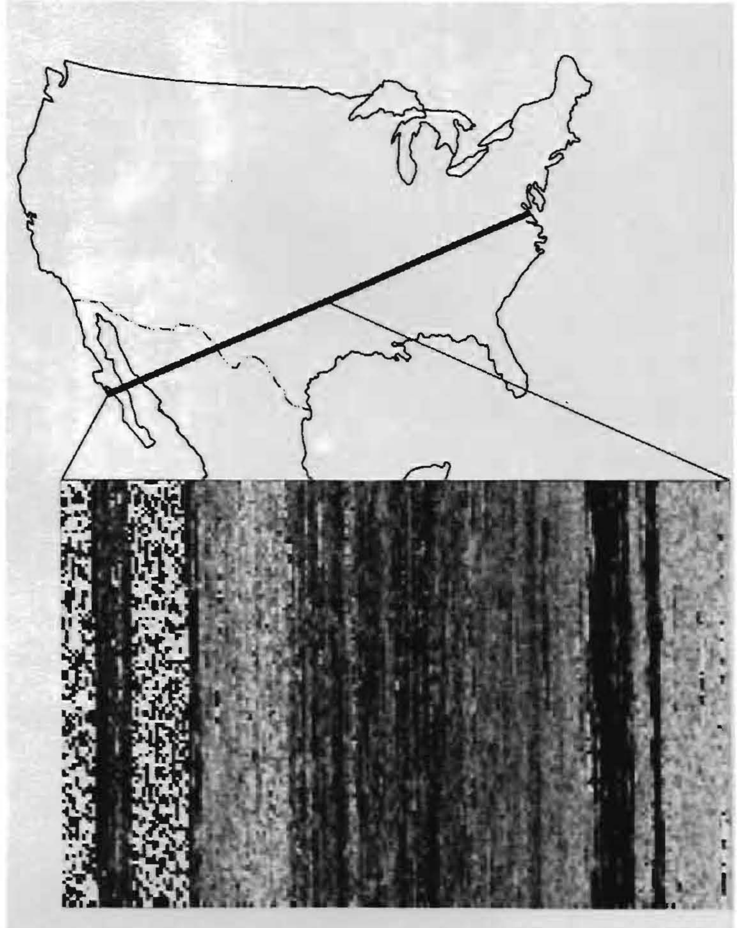
SCIENCE

Besides its orbital flight projects and experiments, JPL has a strongly supportive research and technology program in Earth observations, including oceanography and atmospheric science.

Oceanography

JPL has adopted as an objective in physical oceanography the quantitative determination of air–sea fluxes of heat, mass, and momentum, for incorporation into global climatic models.

It is generally believed that understanding the modifying effects of the ocean on air masses will make a major contribution to understanding climatic variability on scales of seasonal length or longer. The problem involves observing the state of the oceans, understanding oceanic and atmospheric circulation, determining fluxes between the atmosphere and the ocean, and predicting resultant physical changes in the air masses. The basic geo-



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C

A. This image of the Hamersley mountain range of Western Australia was first acquired by JPL's SIR-A. The granite dome at the center, encircled by eroded folds, is the remnant of a volcanic past.

B. The SMIRR spectrum shown here is a part of the swath covered by the Columbia as it passed over North America on the eighteenth orbit of its second flight. When color-coded, the individual picture elements represent water, vegetative ground cover, and exposed rocks, minerals, and varieties of soils. The first dark segment at the left is Baja California; the second is the coast of mainland Mexico.

C. The TOPEX satellite, by bouncing short pulses of energy off the ocean, will map in detail the topography of the ocean's surface.

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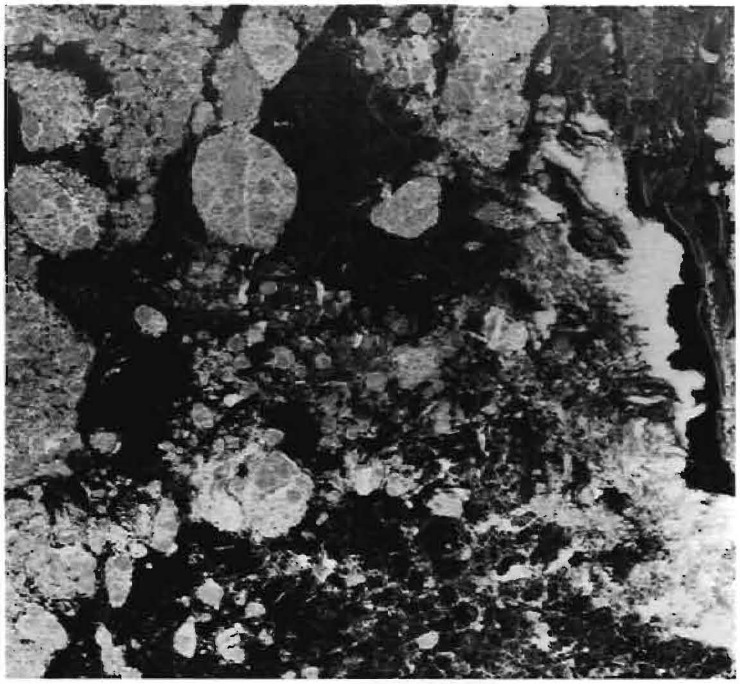


A. This Seasat image of pack ice off the coast of Banks Island in the Beaufort Sea is one of three taken by the satellite over a 6-day period. The trio of images allows accurate determination of ice-floe motion and the changing structure at the pack-ice margins.

B. The Balloon-borne Microwave Limb Sounder (BMLS) starts its first flight into the stratosphere from the National Scientific Balloon Launch Facility at Palestine, Texas, on February 20, 1981. The BMLS measures the abundance of stratospheric chlorine monoxide, ozone, and hydrogen peroxide. These measurements increase our understanding of stratospheric chemistry and the possible depletion of stratospheric ozone by human technological activities.

physical parameters needed for determining air–sea fluxes were measured by Seasat.

Seasat Mean Ocean Topography. Analysis of Seasat altimeter data has resulted in images that display the topography of the geoid, or mean ocean surface, over the entire globe.

The image is a topographic relief map illustrating small-scale features. The results show clearly the relationship between the ocean surface and the changes in gravity caused by the underlying ocean-bottom topography, because the ocean surface follows the solid surface.

The extent to which subsurface features are reflected in the ocean surface is a measure of crustal structure. The images clearly delineate major features such as the deep-ocean trenches on the northwest margin of the Pacific and the Emperor Seamount Chain extending northwest from Hawaii.

The technique represents an optimum method for ocean-bottom feature identification.

Measurements of Water Vapor, Wind Speed, and Wave Height. Seasat, which operated from July to October, 1978, provided the first global pictures from space of water vapor, wind speed, and wave height over the oceans.

All the classic and well-known characteristics of the three quantities are clearly visible in the images.

Some features previously undetectable using conventional measurements (because of sparse surface observations) can be found in the satellite observations.

Wave-height estimates from the altimeter are the first reliable measurements, by any method, of ocean waves during the stormy winter season in the southern hemisphere. The average wave height southwest of Australia is greater than 20 feet.

The global coverage of wind speed and wave height will provide improvements in world-wide sea-state forecasting. The wind measurements will be useful in studying how ocean currents respond to wind forcing.

Climate

JPL has supported the NASA climatic-research program by developing instruments to measure key climatic parameters such as solar irradiance, air–sea fluxes, upper atmospheric properties, and oceanographic parameters.

The Active Cavity Radiometer Irradiance Monitor experiment on the NASA Solar Maximum Mission spacecraft has returned data on fluctuations in the solar irradiance. Some measured fluctuations have been on the order of 0.15 percent (around a mean value of 1,368.20 watts per square meter). Fluctuations of such magnitude could exert a strong effect on the stability of the stratospheric ozone layer.

Atmosphere

The Earth Atmosphere Research Program at JPL is built around the concept of using remote sensing as a tool for studying the physical, chemical, and dynamic structure of Earth's atmosphere.

The upper atmosphere research program is devoted primarily to studies of the stratosphere aimed at determining the impact of natural and human activities on the stratospheric ozone layer.

The field-measurements program covers a range from the conception and design of experiments through the collection of measurements and the analysis and interpretation of data. The program is supported by laboratory and

theoretical studies in spectroscopy, chemical kinetics, and radiative transfer. The program employs three types of instrumentation: high-resolution infrared radiometers; lasers; and microwave radiometers. These instruments are supported by corresponding efforts in laboratory spectroscopy. The results of the laboratory kinetics and field-measurements programs are applied to models of the stratosphere developed at the Caltech campus and at NASA centers.

Balloon-Borne Microwave Limb Sounder. A new atmospheric-measurement technique, microwave limb sounding, has been developed at JPL and used from balloons to provide data on the chemistry of the stratospheric ozone layer.

It is the first experiment to perform microwave measurements by looking down through the Earth's atmospheric limb.

Two flights were conducted at the National Scientific Balloon Facility in Palestine, Texas. Results included the first measurement of the predicted diurnal variation in stratospheric chlorine monoxide, the first simultaneous remote measurement of stratospheric chlorine monoxide and ozone, and the first tentative measurement of stratospheric hydrogen peroxide.

The chlorine monoxide results are important for understanding the potential depletion of stratospheric ozone by the industrial use of chlorine. This is of practical importance because the ozone layer shields living organisms from solar ultraviolet radiation.

Hydrogen peroxide may be a factor in the destruction of ozone by hydrogen chemistry, and measurements made by microwave limb sounding add to the general knowledge of the chemical's impact on the stratosphere. A satellite microwave limb sounding experiment is under study for the Upper Atmosphere Research satellites being considered by NASA.

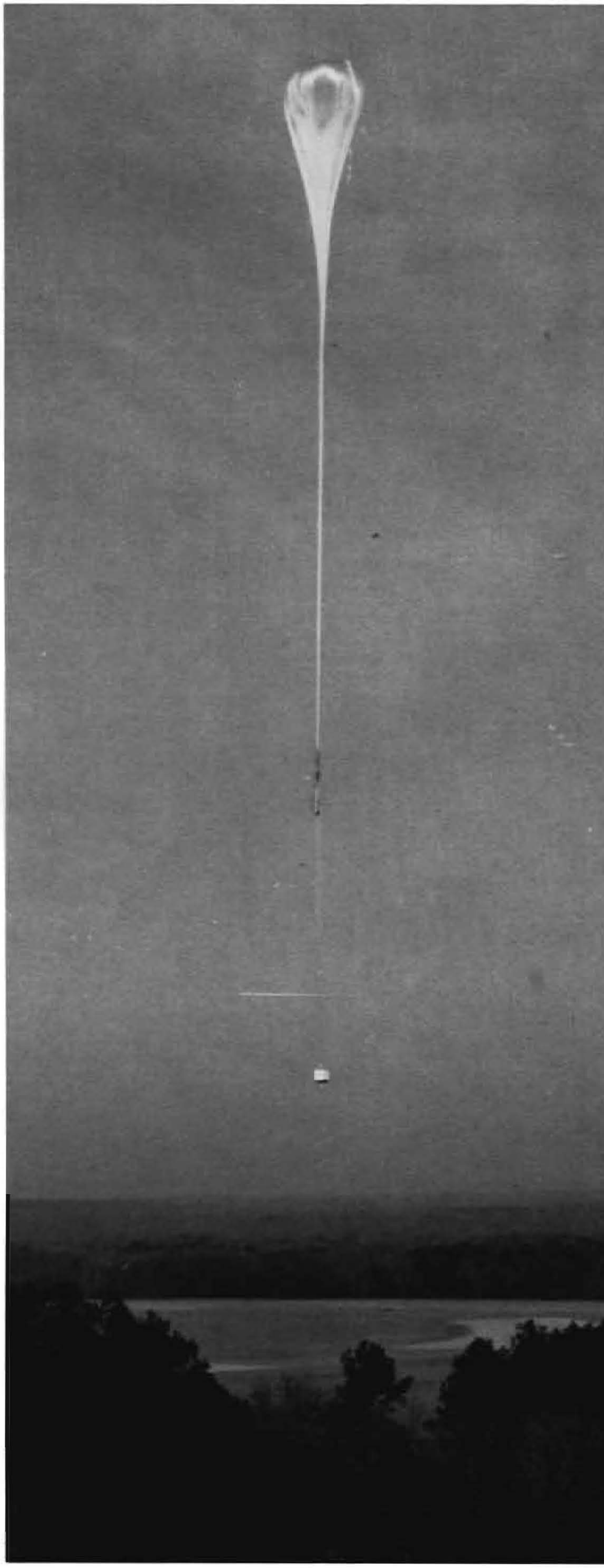
Microwave Pressure-Sounder Aircraft Experiment. The first test flights of the Microwave Pressure Sounder were completed during October and November on the NASA CV-990 airborne laboratory.

The aircraft microwave pressure sounder is a millimeter-wavelength radar designed to verify a new concept for remotely measuring atmospheric pressure at Earth's surface.

Operating at two frequencies at the lower end of the 60-gigahertz oxygen absorption band, the instrument measures differential absorption through a vertical atmospheric column. The observations are compared with theoretical values derived from spectral models and with simultaneous measurements of the atmospheric profile.

Preliminary analysis of the data from three test flights shows encouraging agreement between the observations and the theoretical predictions.

Surface pressure data provided by an operationally deployed microwave pressure sounder would have applications in numerical weather forecasting and in meteorological, oceanographic, and climatic research.



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Potential rooftop solar applications for the San Fernando Valley are mapped by a computer simulation.

JPL continued research, systems management, and other technical and innovative activities in the areas of solar energy, utility systems, energy conservation, transportation, coal, and biomedical technology.

The Office of Energy and Technology Applications sustained those efforts primarily in support of federal agencies including the Department of Energy (DOE), the Department of Transportation (DOT), and NASA. Other activities involved state and city government contracts and some industry-supported research efforts.

ENERGY AND ENERGY-CONVERSION SYSTEMS

While federal funding for solar-energy research declined in 1981, work continued at the Laboratory on important energy technologies and their applications. One group used solar-energy equipment to scan the skies in a new study of gamma-ray emissions from Cygnus X-3.

Photovoltaics

The year 1981 was a time of transition for the Photovoltaics Lead Center at JPL. In line with changed Administration policy, many budget and planning options were developed and discussed with the Department of Energy, to accommodate reduced funding levels.

Other activities included development of the "Photovoltaic Program Sunset Review," a Congressionally mandated review of all DOE programs.

Analyses verified that the technology exists for allowing industry to produce both flat-plate and concentrator photovoltaic modules for less than $2.80 per watt (peak) (in 1980 dollars). This assumes that the technology would be implemented in plants already producing approximately 10–15 megawatts (peak) per year of product.

An extensive analysis of the Japanese photovoltaic industry's activities concluded that the Japanese photovoltaic technology-development program may soon surpass that in the United States. There are some indications that the Japanese government's research and development spending has already increased beyond that of the United States. U.S. industry will have to move fast to maintain the two- to three-year technology and production lead that it has.

In the systems area, two residential-experiment stations are operational, one in Massachusetts and one in New Mexico. Thirteen prototype photovoltaic residences are being tested at the two sites. A family of residential "preferred designs" was completed.

Since photovoltaics lend themselves to distributed rather than centralized applications, issues involving local utilities were studied. Included were the issues of solar-array electrical characterization and safety. Finally, advanced concepts for photovoltaic power conditioners for

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residential applications were investigated, and a number of conceptual designs prepared. Current state-of-the-art power conditioners for residential applications were also assessed.

Solar Thermal Power Systems

The Thermal Power Systems Project is developing parabolic dish modules for producing electricity and industrial process heat. A dish 11 meters (36 feet) in diameter produces 20–25 kilowatts of electricity using a receiver/heat-engine/alternator power-conversion assembly at the focus of the dish. The 75–85 thermal kilowatts can be used without conversion for industrial process-heat applications.

Solar-dish–Stirling-module tests at the JPL Parabolic Dish Test Site at Edwards Test Station in the Mojave Desert were successful. The Stirling-cycle power-conversion assembly mounted on an 11-meter JPL solar test-bed concentrator fed about 20 kilowatts of electricity into the Southern California Edison Company's grid.

An organic Rankine cycle power-conversion assembly was tested and will be installed on a concentrator at the Parabolic Dish Test Site for solar testing early next year. That will be followed by a solar Brayton-module test at the site.

Steam was provided by a Fresnel-type parabolic dish for curing concrete blocks at the Capitol Concrete Company in Topeka, Kansas. A dish installation, because of its intrinsic high efficiency, uses less collection area than other types of solar collectors, such as troughs and flatplate, for producing industrial-process heat.

Salton Sea Solar-Pond Experiment

A design study for salt-gradient solar-pond electric-power plants in the California Salton Sea has shown the concept to be technically, environmentally, and economically feasible. A five-megawatt proof-of-concept experiment is being designed for installation in the mid-1980s. A commercial installation will consist of 50-megawatt modules that can be sequentially installed to reach a total capacity of 600 megawatts.

A salt-gradient solar pond is a body of water in which heavy brine sinks to the bottom and low-salinity water rises to the surface. A controlled, nonconvecting central zone prevents lower brines from mixing with the surface. Large quantities of thermal energy are captured and stored in the lower brines. Working temperatures of 80° Celsius (176° Fahrenheit) have been demonstrated.

Shaft power will be produced by using the hot brines as an energy source for an organic Rankine engine. The large thermal capacity of the solar pond supplies energy on a 24-hour-per-day basis and enables the electric plant to generate power.

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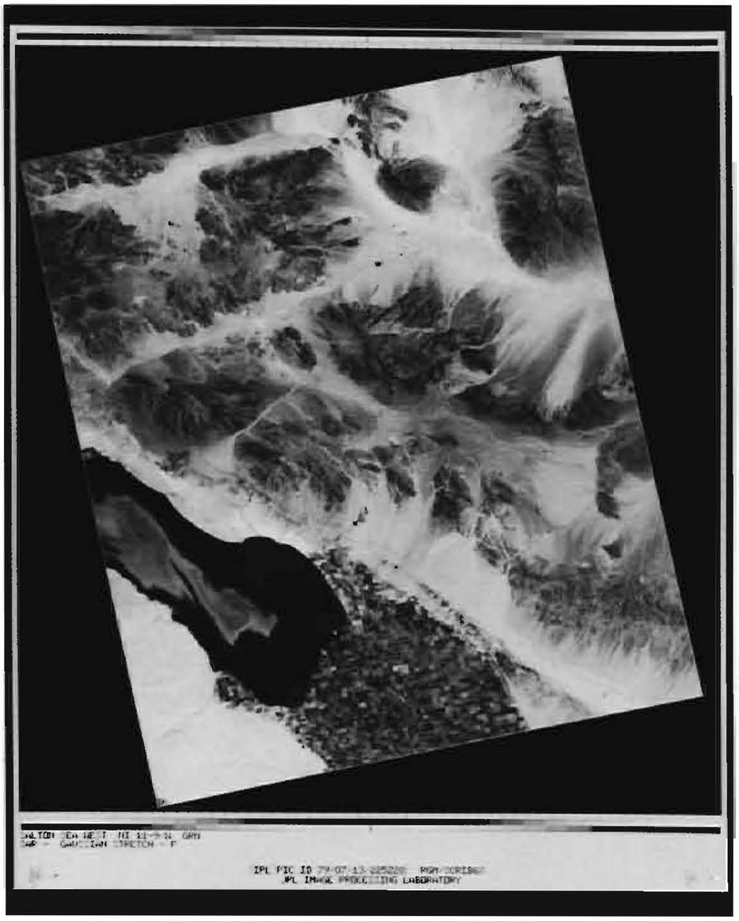
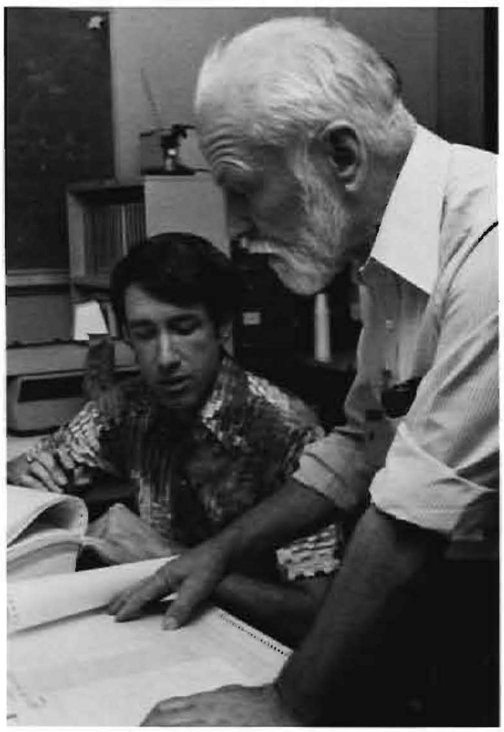


A. *Carlisle House is a photovoltaic residence located in Carlisle, Massachusetts, approximately 20 miles northwest of Boston. When occupied, the house will be monitored for system performance.*

B. *This solar test-bed concentrator, measuring 11 meters (36 feet) in diameter, is located at the Parabolic Dish Test Site at Edwards Test Station. Such concentrators are used to test and evaluate solar power systems at temperatures ranging from 300 to 1700° C (572 to 3000° F).*

C. *A view by Landsat of the Salton Sea, California, where a solar pond experiment is being conducted.*



Gamma-Ray Astronomy Experiment

A suspected pulsar—Cygnus X-3—has been observed by astronomers using as a high-energy observatory two mirrored parabolic dishes intended for solar energy research.

While supernovas produce great outbursts of visible light, only four have been observed in the Milky Way in recorded times, the most recent being Kepler's Supernova in 1604. Cygnus X-3 may have resulted from a supernova that occurred within the last few centuries, but that remained unseen because of an obstructing curtain of interstellar dust and gas. Supernova remnants can, however, be visible in the gamma-ray portion of the spectrum, and Cygnus X-3 is the brightest ultra-high-energy gamma-ray source in the sky.

The parabolic dishes, located on the JPL site at Edwards Air Force Base, were used to observe Cygnus X-3 at ultra-high gamma-ray energies above 100-billion electron volts—one of the highest-energy astronomical observations ever made.

These ultra-high-energy gamma rays were rendered visible by the Cerenkov effect: a faint flash of light lasting mere nanoseconds that is created when such gamma rays strike the atmosphere. This flash can be observed by a fast photomultiplier tube placed at the focal point of a large parabolic mirror, like those at JPL's desert test site.

The mirrors have a focal length of about 6 meters (20 feet). They are movable through elevation and azimuth under computer control so that astronomical objects can be tracked while Earth rotates. The large size of the mirrors, their good optical quality, their high reflectivity, and the fact that there are two of them, spaced about 30 meters (100 feet) apart, make them uniquely useful for observing the Cerenkov effect.

When an ultra-high-energy gamma-ray particle strikes the atmosphere, it produces a shower of secondary particles: electrons, positrons (antimatter electrons), and lower-energy gamma-ray particles. If the ultra-high-energy particle strikes the atmosphere with sufficient energy, the secondary electrons and positrons will move at relativistic speeds—very nearly at the speed of light.

The Theory of Relativity states that no particles other than light can reach the speed of light in a vacuum. However, in air the speed of light is lower than in a vacuum. Nonlight particles can break that lower speed limit, so long as the ultimate vacuum limit is observed. Ultra-high-energy particles breaking that lower limit produce a "light boom" in Earth's atmosphere—just as a supersonic jet produces a sonic boom.

This "light boom" manifests itself as a cone of visible radiation. The cone is very flat, almost a disk, and travels nearly along the path of the original particle. Long after the shower of secondary particles has been absorbed by the denser air at lower altitudes, the disk of Cerenkov radiation strikes the ground and produces the flash that is observable with the JPL solar-thermal concentrators.

UTILITY SYSTEMS

The Utility Systems Program is analyzing developed technologies, with the goal of integrating new energy sources into existing electric utilities, especially in terms of communication and control.

Significant progress was made in communicating directly over power lines. Concepts have been tested and verified using the San Diego Gas and Electric Company system. Of particular importance is the development of an analog simulator with a wide-frequency response that, to study propagation problems, will simultaneously provide 60 hertz and its harmonics on feeders and will provide 5 kilohertz to 50 kilohertz. This has required the resolution of some unique technical problems.

Application of the simulator to broader problems in integrating new generators is being explored. The system and the digital Electric Power System Simulator provide excellent tools for understanding electric power systems.

COAL SYSTEMS

The advanced Coal Extraction Project has prepared design requirements for an underground mining system. Improved productivity in coal mining is being emphasized. The project has also identified the U.S. coal resources to which the system could be applied, beginning in the next century.

TRANSPORTATION SYSTEMS

Research in transportation reached across a wide spectrum in 1981, from propulsion for railroad locomotives to safer fuels for jet aircraft.

Automated Mixed Traffic Transit Development

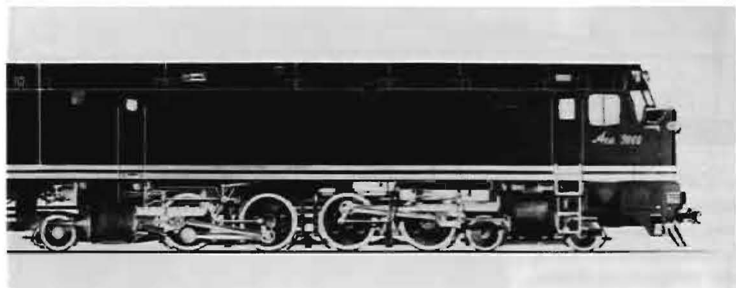
A new experimental Automated Mixed Traffic Transit (AMTT) vehicle was under development in 1981 under DOT-Urban Mass Transit Authority (UMTA) sponsorship. The AMTT concept is an innovative, low-cost transportation option useful at sites where low-speed tram-type transit is needed. Automated vehicles follow a route defined by an excited guidewire buried in an existing road or walkway, with preprogrammed stops for passenger pickup.

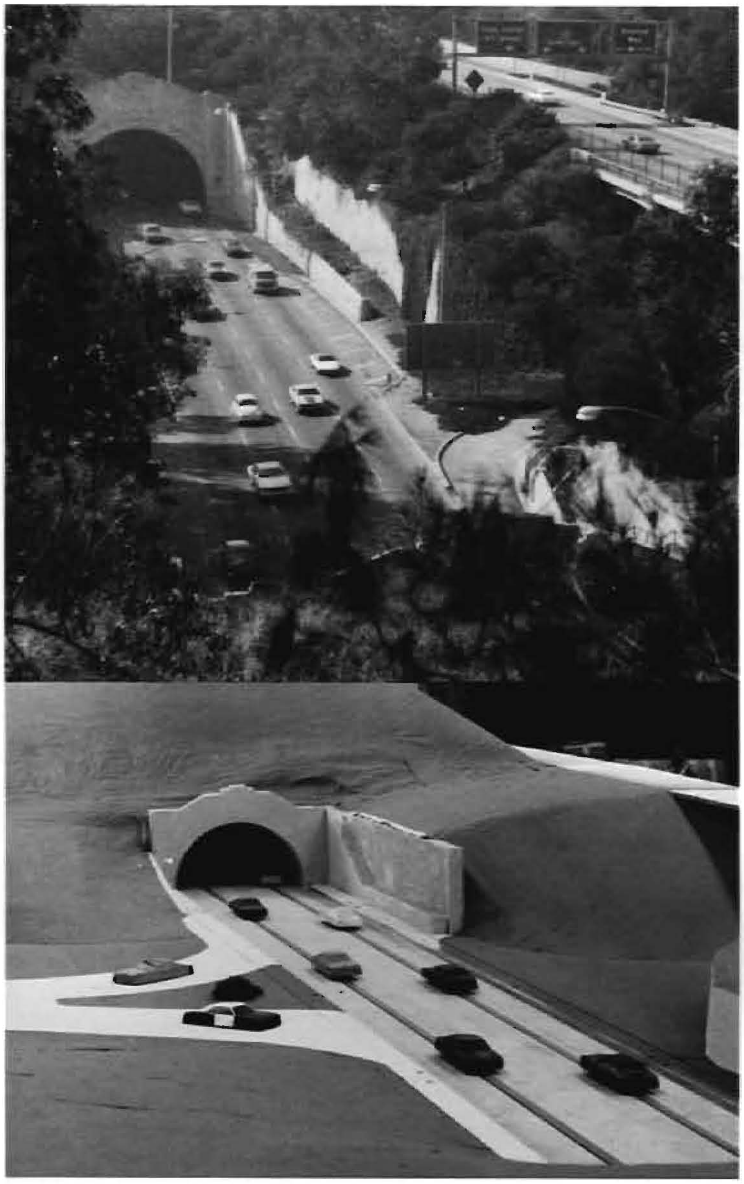
JPL has been developing the technology for the AMTT since 1975, first with the instrumentation of a small tram, and more recently with a new nine-passenger, enclosed vehicle. A system of optical sensors that detects obstacles or conflicting traffic and stops the vehicle when necessary is a key element of the concept.

Alternative Locomotive Propulsion

A three-year study of railroad locomotives, aimed at reducing the dependence of U.S. railroads on petroleum fuels, was completed for the Department of Energy. Alternative fuels, types of engines, and engine modifications were examined for their petroleum-saving potential.

The study identified the coal-fired locomotive as the best alternative to diesel-electric locomotives in terms of fuel availability, overall cost, and maintenance. Additional research and development of the coal-fired locomotive are planned. JPL envisions a more advanced, higher-efficiency coal-fired locomotive with electric drive motors, rather than the present reciprocating direct-drive system.





D

A. *An advanced, experimental, nine-passenger vehicle used for testing the Automated Mixed Traffic transit concept. The first vehicle is in the background.*

B. *A coal-fired locomotive with electric drive motors is being considered as a successor to the diesel-electric locomotive.*

C. *The Hybrid Power Train Mule Vehicle being fabricated at Triad Services, Inc., in Madison Heights, Michigan. The hybrid power train is composed of an electric motor (left foreground) and a 4-cylinder gasoline engine (right foreground).*

D. *To minimize the impact of freeways as a source of environmental noise, subterranean freeways are being considered. To study the effects on air quality in and around such a construction, JPL has designed and built the Highway Intermittent Tunnel Simulator, shown in the lower photo.*

Electric and Hybrid Vehicle Research

A modified Audi 5000 hybrid test vehicle, developed under DOE contract by General Electric and Volkswagen, was received in 1981 by JPL for testing. The hybrid test vehicle uses an internal-combustion engine and an electric motor for propulsion and has a microprocessor control that allows either or both power sources to operate the vehicle. Analytical studies indicate that the hybrid vehicle could reduce petroleum consumption in urban driving by about 70 percent and in combined urban and highway driving by about 50 percent, compared with a projected 1985 internal-combustion-engine-powered passenger car of the same interior size.

Advanced lead-acid and nickel-iron batteries were tested in several vehicles, using the JPL dynamometer laboratory and a test track at Edwards Test Station.

A JPL computer program was improved, enabling nationwide users to simulate performance of hybrid and advanced vehicles and components, including batteries, motors, and transmissions.

Antimisting Fuels

Under a joint United Kingdom–United States program, JPL is developing an antimisting fuel technology intended to reduce postcrash fire hazards on aircraft.

The program at JPL is funded by the Federal Aviation Administration, to provide scientific data and new technology in the field.

Initial experiments showed that the mechanism that prevents mist formation and its ignition during a survivable crash-landing is related to the development of high-tensile viscosity, which is a physical antimisting characteristic inhibiting breakup of the fuel. Image-enhancement techniques were used to quantify fuel breakup in terms of fuel loading, droplet size, and cumulative particle distribution.

Highway Tunnel Research

Systems for ventilating covered, subterranean freeways are under study. Information on how air circulates in and around closely spaced, parallel tunnels, and the impact of traffic on that circulation, is needed to create a cost-effective design for depressed freeways.

To develop the necessary information, the Highway Intermittent Tunnel Simulator was designed and constructed at JPL under a DOT–FHWA (Federal Highway Administration) contract to analyze various conditions affecting air quality along and about passively ventilated tunnels. Data collected from the 3-percent-scale facility compares favorably with full-scale field tests: airflow patterns due to traffic can be predicted from small-scale tests.

Information generated from the studies will be used to aid in the future design of depressed, partially covered freeway systems.

MAFIS helicopter laser platform on board an AH-1S Cobra helicopter during a U.S. Army field test.

JPL has begun to expand its base of sponsorship by more actively pursuing work with the Department of Defense (DOD). At the beginning of fiscal year 1981, a new program office was formed to serve as a focal point for the acquisition and management of all DOD work at JPL.

The new Defense Programs Office is actively pursuing work with the U.S. Air Force, Army, Navy, and Defense Advanced Research Projects Agency (DARPA). A Memorandum of Understanding has been executed with the U.S. Air Force Space Division, which should provide the basis for substantive project management assignments in areas in which JPL has significant relevant experience. Similar agreements are being considered for the Army and the Navy.

In October 1981, a Caltech–JPL Washington office was established to facilitate liaison with potential sponsors in the Washington, D.C., area. The office is in Crystal City, Virginia, and the JPL Navy Space Program Office is housed there. Also, the office serves as a home base for others in the Caltech–JPL community when they are in Washington on business.

Currently funded efforts under the Defense Programs Office range from large projects, for which JPL has full project-management accountability, to smaller advanced-technology tasks that draw from the broad technology base at JPL.

AUTONOMOUS SPACECRAFT PROJECT

Work continued on a new project for the Air Force Space Division to achieve, by the end of the decade, a high degree of defense-satellite autonomy and independence from ground stations. Autonomy features on planetary spacecraft, required by long two-way communication times, have resulted in the development of a unique set of skills at JPL that have a direct application to this national-defense need.

In 1981, goals were developed for the Air Force Autonomous Spacecraft, and an assessment was made of the autonomous operational capability of the Defense Space Communications Satellite III (DSCS III), an advanced geosynchronous communications satellite to be launched during 1982.

Future efforts will include: 1) compilation of JPL's autonomy experience into a document for Air Force/industrial use; 2) design, development, and demonstration of a prototype fault-tolerant, computer-based spacecraft subsystem capable of implementing ground-based routine maintenance and fault-correction functions on future defense satellites; and 3) development and flight demonstration of the concept either as a Space Test Mission or as part of an ongoing program such as DSCS III. The project will be conducted over a five-year period and will involve an industrial contractor during flight implementation.

A

MOBILE AUTOMATED FIELD INSTRUMENTATION SYSTEM (MAFIS)

MAFIS is a transportable instrumentation system that will enable large-scale simulated battlefield test exercises to be monitored and evaluated. Infantry, ground vehicles, and aircraft will be instrumented with engagement-simulation, communication, and position-location functions. MAFIS is under development by JPL for the U.S. Army Training and Doctrine Commmand.

A central instrumentation facility will provide communications and the control, display, and recording of test activities over a 50- by 50-kilometer (30- by 30-mile) area. MAFIS will consist of 200 universal field elements, a communications network, and a command and control center—all integrated and scheduled for delivery to the Army as an operational system by the end of 1985.

JPL will provide the technical management and system design for MAFIS. A preliminary system design review was completed in 1981, and a request was issued to industry late in the year for proposals to produce the universal field elements and a command and control center. The position-location network will be produced in-house by JPL.

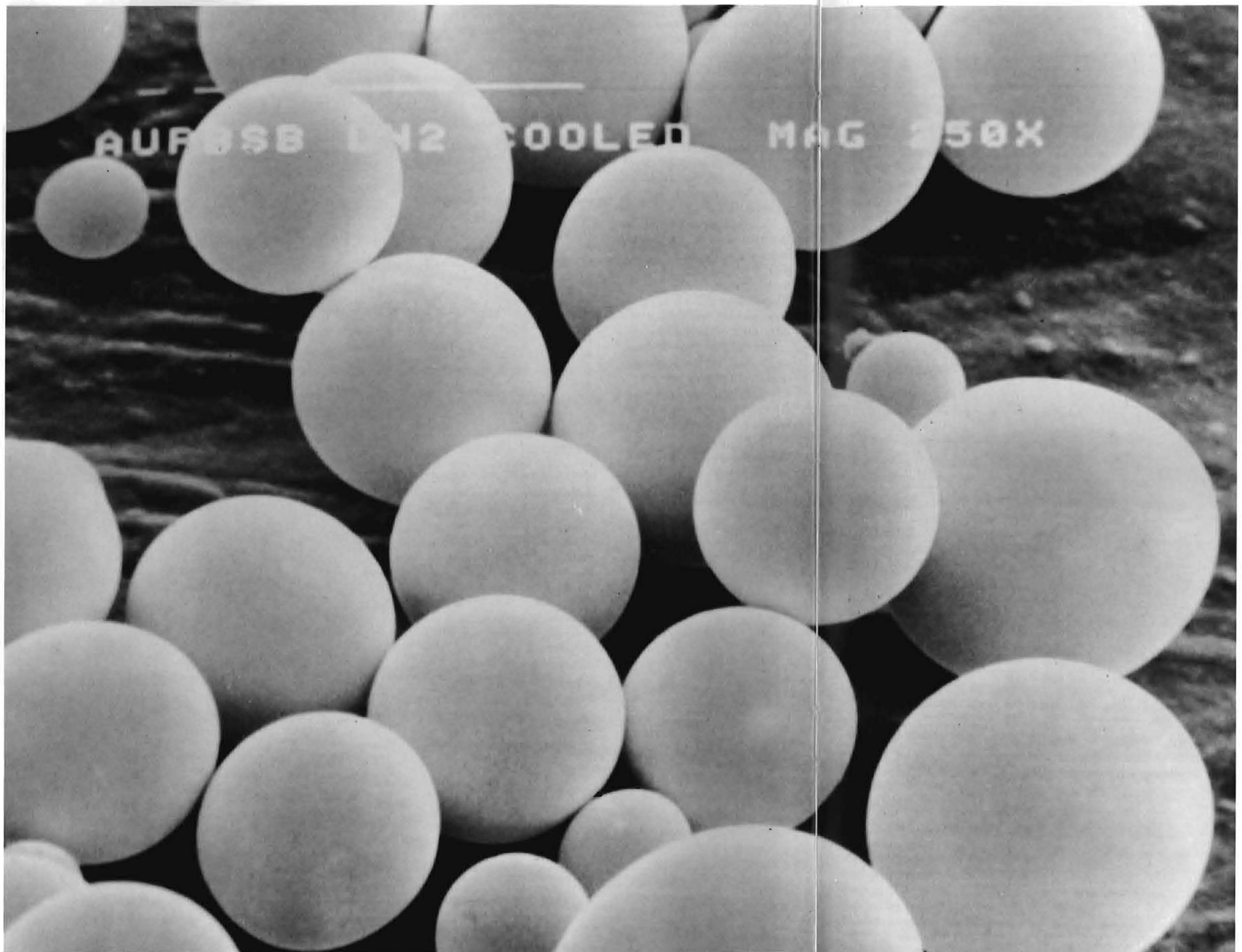
A three-month test was conducted during 1981 to establish the feasibility of using a medium frequency, differential phase measurement method as the MAFIS position-location instrumentation technique. The test system, designed and developed by JPL over 18 months, consists of a network of four phase-synchronized transmitters at appropriate facilities surrounding Fort Hood, Texas, and three mobile receivers in test vehicles. The test results established that position-location accuracy within 10 meters can be achieved—the design goal for MAFIS.

Another major accomplishment in 1981 was the design and development of an engineering model of a helicopter laser platform (HLP). A test at Fort Hood in May demonstrated the feasibility of using the HLP as part of an air-to-ground engagement simulation system. The HLP is a laser-pointing, electro-optical mechanical instrument providing simulation of the Tube-launched, Optically tracked, Wire-guided (TOW) missile that is launched from attack helicopters.

B

A. Workers install guys and insulators on the MAFIS transmitter tower. This 61-meter (200-foot) tower is fully portable: it can be erected in less than 6 hours and taken down in less than 5.

B. Installation of the MAFIS helicopter laser platform device on the Cobra helicopter.



Assemblage of solid spherules of amorphous alloy with diameters ranging between 40 and 120 micrometers.

Research and development in nonspace applications continued at the Laboratory. The work covered such areas as biomedical technology, computer-aided design and manufacturing, and very-large-scale integration (VLSI) of circuitry.

VLSI

An in-house capability for the development of customized, large-scale integrated circuits is being established at JPL. Such a center for LSI/VLSI computer-aided design will give designers access to state-of-the-art software tools for circuit architecture, layout, and design verification.

It is anticipated that the greater part of JPL's needs for LSI and VLSI in the future can be met either by general-purpose commercial products as they evolve, or by standard families of chip sets designed for special applications demanding high reliability and produced in large volume.

Custom development of LSI/VLSI chips will take place when available off-the-shelf components do not meet special needs, or when cost and performance benefits can be achieved by a design that incorporates JPL's knowledge of the application and its requirements.

Custom design as an implementation option will become increasingly more attractive as the costs of design are reduced.

A VAX 11/780 will serve as the dedicated host for design support. The system is expected to be operational in fiscal year 1982.

Industry will provide manufacturing, using an approach advocated by Professor Carver Mead of the Caltech Computer Science Department and his coworkers, and being implemented by DARPA for its university design-research community. The number of design projects at JPL is small, but is rapidly growing.

A prime objective of the Product-Assurance Technology Program now being pursued at JPL, with joint sponsorship by DARPA and NASA, is to determine approaches that can be used in the design, fabrication, and qualification of custom LSI components for highly reliable and radiation-hardened electronic systems.

Technology for interactive use with mask- and wafer-fabrication companies is being developed and validated. Equipment is also being assembled for evaluating special test structures fabricated on wafers and for evaluating chips containing circuits, for both product assurance and reliability assessment.

COMPUTER-AIDED DESIGN

Significant progress was made in 1981 in the revolutionary, swiftly developing field of computer-aided design (CAD) and manufacture. JPL has purchased new hardware, developed new software, and expanded its facilities for accommodating CAD operations and research.

The main centers of design activity at JPL are the Computervision Facility and the Computer Graphics Laboratory. The former has the capability for producing three-dimensional designs for both electronic and mechanical equipment. Through the use of its computer and graphic-display terminals, the facility can create preliminary conceptual designs of state-of-the-art equipment, as well as produce finished, detailed fabrication drawings for equipment ready for manufacture.

A CAD training program for draftsmen and designers has created a cadre of personnel having the necessary expertise to effectively use the CAD system.

The Computer Graphics Laboratory increased its capabilities in 1981 with the acquisition of a VAX 11/780 computer that significantly enhances the processing function. The laboratory specializes in the conceptual design of advanced spacecraft and ground equipment.

A third area of CAD activity is optical design. The computer-aided optical design system is being operated in coordination with a similar system at the University of Arizona, and has been used in designing the Infrared Astronomical Satellite, the Multispectral Mapper, the Microwave Limb Sounder, the Wide-Field and Planetary Camera, and the Galileo spacecraft's optical system.

CAD systems are being studied to judge their effectiveness in new applications, including the Shuttle mission instrument track evaluator, the interactive timeline design program for space missions, the Galileo scan platform and sun-shade geometry, Seasat data analysis, and printed wiring-board design.

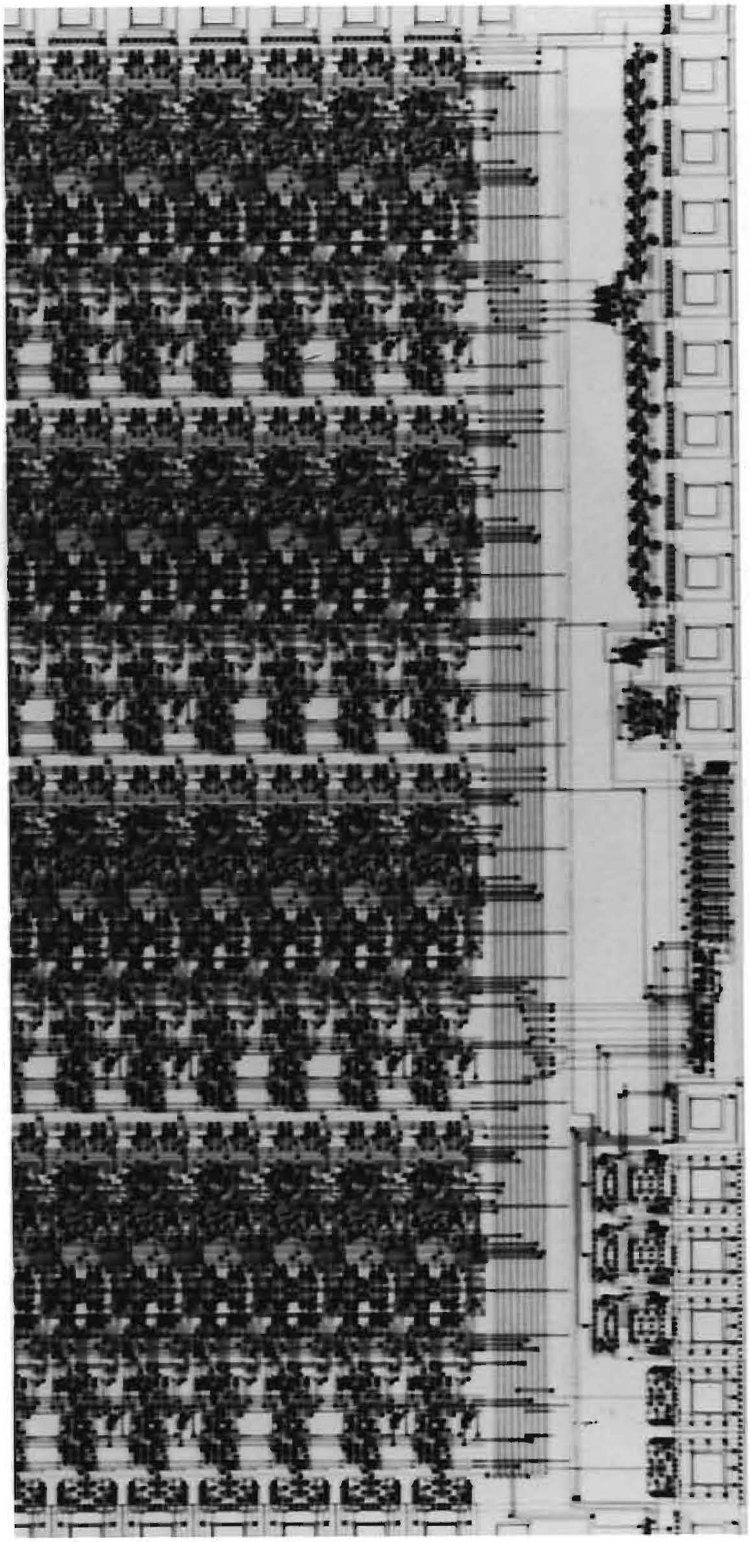
TELECOMMUNICATIONS TECHNOLOGY

The DSN Advanced Systems Program develops the technology for meeting anticipated mission requirements in the areas of spacecraft communication, radio navigation, and radio science. Low-cost missions in the 1990s and beyond will require a communication system that enables low mission-operations costs.

A promising technique for reducing spacecraft navigation costs and improving angular position accuracy is currently under final development. This technique is delta differential one-way ranging, or delta very-long-baseline interferometry (VLBI). It uses radio interferometry techniques to precisely measure spacecraft angular position relative to extragalactic radio sources such as quasars. Operations cost savings of at least 50 percent are realizable in the generation, transmission, and processing of range and Doppler data. A demonstration of the technique, using the Voyager 2 spacecraft, surpassed expectations. The technique has been adopted for Galileo navigation. Work is under way to improve system performance to the 5 nanoradian level through improvements in radio-source position measurements, troposphere calibration techniques, and microwave delay calibrations.

Navigation, radio science, and command will benefit from the higher-frequency operation afforded by a new X-band uplink system, which is expected to yield an order-of-magnitude improvement in two-way Doppler stability.

A newly assembled common-aperture dual-frequency feed system will allow S- or X-band transmission and simultaneous broadband reception of both S- and X-band frequencies. This capability will allow the precise removal of transmission media effects and will thereby improve navigation and radio-science performance, particularly in near-Sun environments.



A

A number of techniques are under study to improve the performance of existing and new antennas at all frequencies. Feed-array concepts are being developed to correct for small-scale antenna pointing errors and reflector surface distortions.

Analysis of radio-frequency interference (RFI) at Goldstone was greatly enhanced using the recently completed RFI surveillance system. The portable system features a rotating medium-gain antenna and a 300-megahertz, 1-million-line, digital spectrum analyzer. Surveys conducted in the DSN S-band receiving frequency allocation demonstrated the high resolution available under computer control.

BIOMEDICAL TECHNOLOGY

The Office of Biomedical Technology was established in 1967 as one of the first nonspace research activities at JPL.

The goal is to apply the expertise of the Laboratory's engineering and scientific staff to improving the health of humankind. Techniques and materials developed at JPL for space applications are used in the effort.

More than 30 individual research tasks within the Biomedical Program draw on JPL capabilities in computer image processing, materials research, and advanced instrumentation. More than 100 people are involved at least part-time.

JPL has a long history of funding in medical research by the National Institutes of Health (NIH), the Veterans' Administration, and the Food and Drug Administration. About one-half of the Biomedical Program's activities are funded from these and other non-NASA sources. The remaining half, funded by NASA, support NASA programs to determine physiological reactions of humans in space and to direct the transfer of space technology to the private sector.

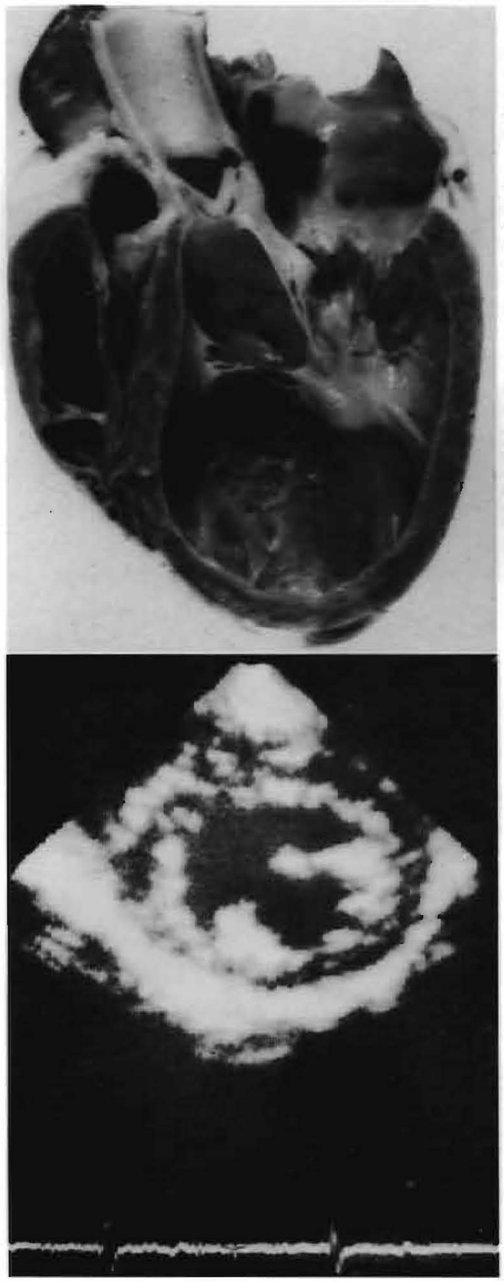
Automated Cervical-Cancer Screening

JPL, in collaboration with UCLA pathologists, has completed a four-year feasibility study of automated analysis of the Pap-smear procedure. A computerized microscope system finds and measures 10,000 cells per sample and classifies each as either normal or abnormal. The results were compared with the pathologist's diagnosis to demonstrate the accuracy of the system. A cost-benefit analysis indicates that significant cost savings are possible with automation. JPL will begin development of a clinical prototype in 1982. The unit will employ a unique JPL-developed multiple-microprocessor computer system to attain processing speeds of up to 1,000 cells per minute.

Medical Ultrasound

The Medical Ultrasound Program at JPL uses recent technological advances in ultrasound physics, image processing, and clinical research to bring new ultrasound methods into practical use in clinical environments and in the space program.

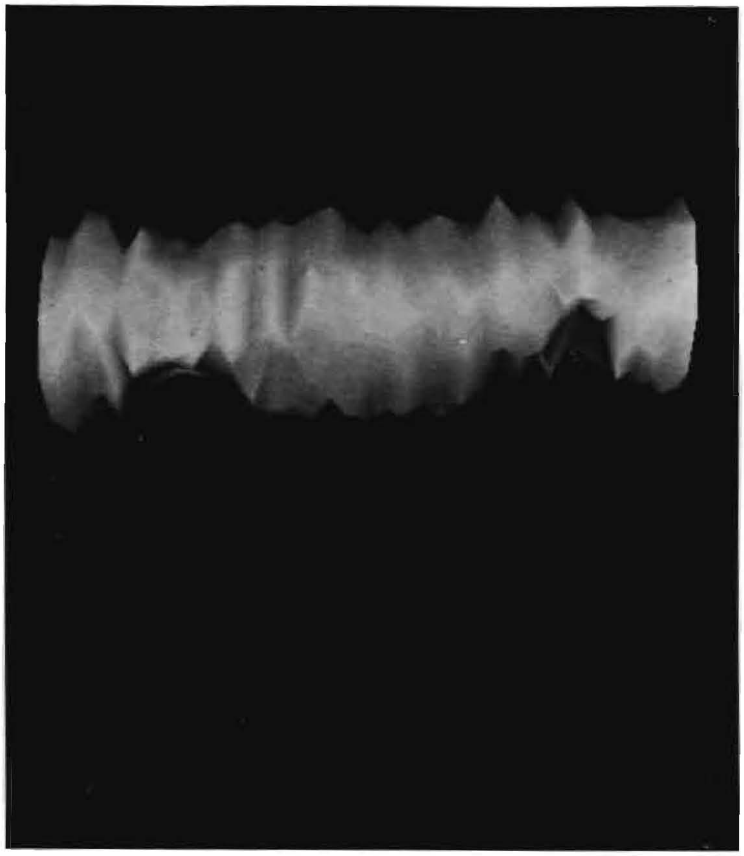
The current ultrasound projects for NASA include cardiovascular ultrasound imaging research; a project for developing ultrasound instrumentation for the pre- and postflight cardiovascular examination of astronauts and mission specialists; and consultation for NASA on the selection of the spaceflight



B

A. A trial VLSI fabrication of a four-multiply-and-add chip was made and tested at JPL. Its first major application will be in JPL's Image Processing Laboratory.

B. The human heart (upper photograph) can be imaged without surgery through the use of ultrasound (lower photograph). The cross-sectional ultrasound image is one frame taken from a videotape recording of a beating heart. Images such as this allow accurate measurements of the heart-wall dimensions—a valuable tool in monitoring the health of astronauts.



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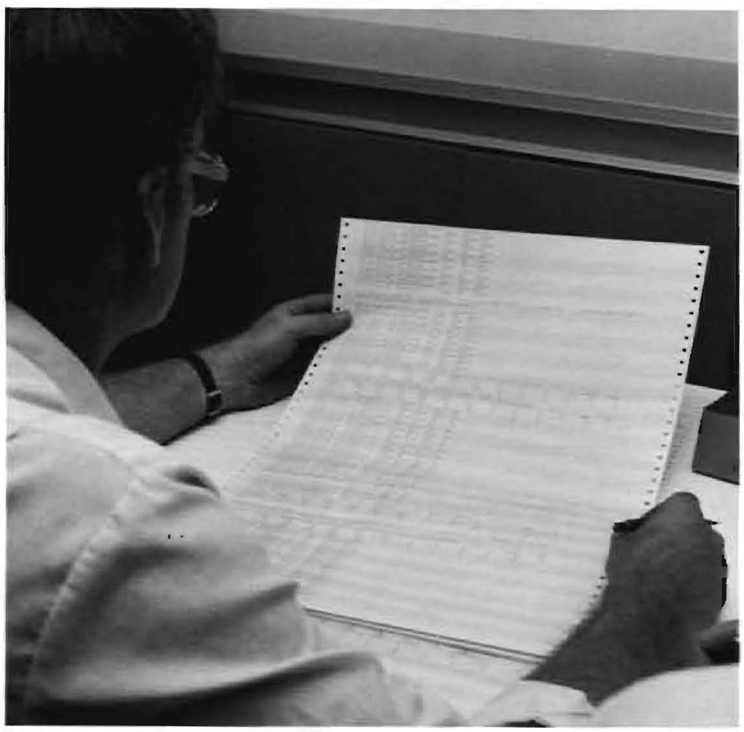


ultrasound instrument for inflight cardiovascular experiments and for crew health examinations.

Projects for the National Institutes of Health include the development of a new ultrasound instrument for the high-resolution imaging of deep arterial lesions using a swept-frequency methodology. The ability of commercial ultrasound scanners to quantify the early development, progression, or regression of atherosclerotic lesions in the carotid and femoral arteries of patients is also being explored.

The NIH projects are being performed in collaboration with a leading researcher at the Los Angeles County–USC Medical Center.

ENVIRONMENTAL TECHNOLOGY

The Viking lander gas chromatograph–mass spectrometer is being adapted as a field-portable toxic-gas analyzer. Laboratory mechanization has been initiated with industrial sponsorship.

A second industry–NASA-sponsored project involved the development of a prototype laser remote-sensing system that can detect and quantitatively measure methane leaks at a range of 30 meters (100 feet) In field tests, the laser system was used to measure methane concentrations at a sanitary landfill and to measure methane from previously identified underground natural-gas pipeline leaks.

INFORMATION SYSTEMS TECHNOLOGY

A pilot demonstration was initiated of an on-line, interactive data base for remotely sensed ocean data. In the Ocean Pilot System, data from several instruments is entered in a single data base that can be easily and economically accessed by several users. Users need not travel to JPL, but can access the data from home institutions by telephone. Some preliminary data sets are on line, and user response has been good.

The Uplink Process Control Task is planned to drastically reduce the time and cost of developing complex command sequences for spacecraft. As part of the task, a commercially available color graphics microprocessor computer has been programmed to provide an automated work station that mission planners can use to develop sequences involving many instruments and targets. It has been demonstrated to be quicker and cheaper than existing methods, and the Voyager and Galileo projects are considering using it as part of their mission operations and planning. Several other NASA and DOD programs have indicated an interest in adopting the work-station design to their needs.

DATA-BASE MANAGEMENT SYSTEMS

The ground data management systems that support scientific data collection have typically been custom built for each spacecraft at high cost. The use of commercially available data-base management systems, on the other hand, has generally been limited to the control of datasets and tapes in archives.

JPL, however, has pioneered the use of commercial data-base management systems to manage remotely sensed scientific data bases. During 1981 the Laboratory began implementing, on the

Univac 1100/81 computers, a multimission "Mark IV Data Records System" that uses a commercial data-base management system (DMS 1100).

JPL also has investigated and documented the NASA data-base management system requirements that are not supported by commercial vendors. The intent is to augment general-purpose, off-the-shelf systems with a minimal number of JPL-customized programs, to achieve more flexibility and lower costs than older systems.

REMOTE-SENSING TECHNOLOGY

In the JPL remote-sensing technology program, instrumentation and techniques are being developed for measuring planetary atmospheres and surfaces (including Earth's) from space.

Passive sensor systems depend on emitted or reflected radiation for their signals. A key component of one type of passive system is the Infrared Imaging Detector Array.

Other remote-sensing applications require an active source, such as a highly collimated laser beam, to examine the atmosphere. Recent research has demonstrated the need for continuously tunable lasers of high sensitivity and specificity, and has led to the development of a tunable laser for remote-sensing applications.

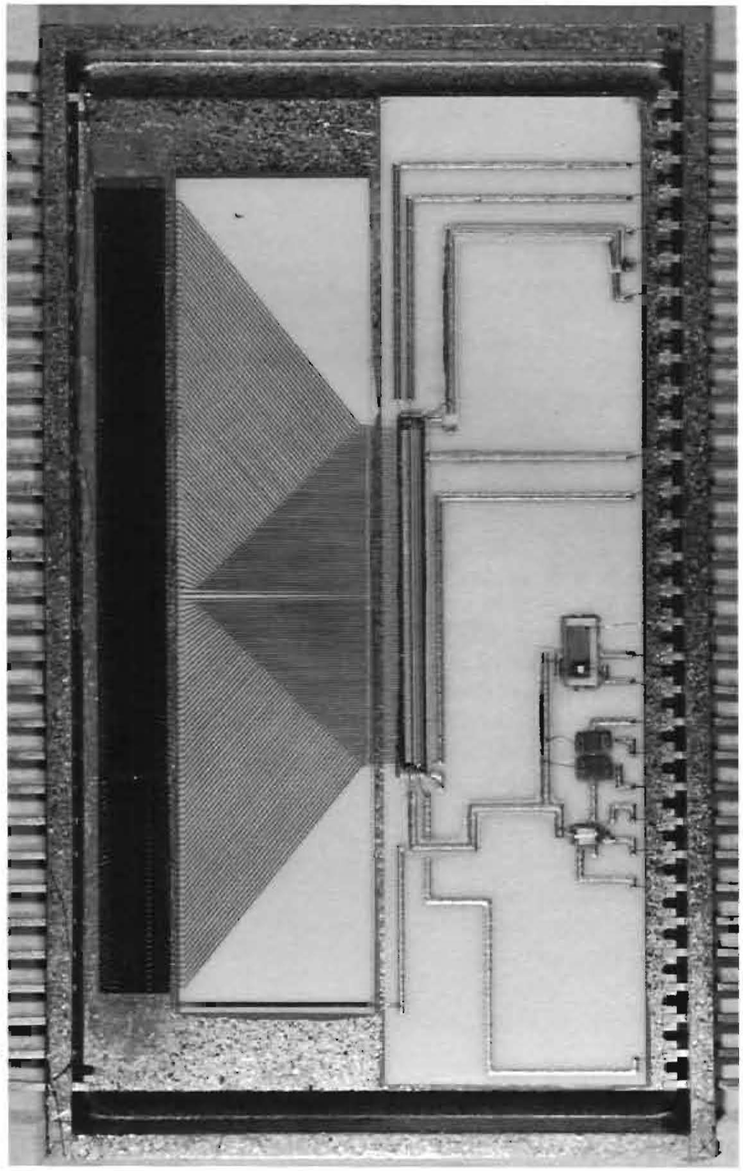
Detector Arrays for Infrared Imaging

Infrared imaging offers the possibility of detecting and discriminating between constituents of atmospheres and of improving discrimination of geologic units.

The development of solid-state infrared detector arrays may provide a new capability for future planetary and terrestrial missions. Design and development of the focal-plane array for the Galileo near-infrared mapping spectrometer revealed that extremely high performance could be obtained by using indium antimonide photodiodes.

Later development resulted in an integrated 128-element linear imager for the 1- to 5-micrometer region. An array of 128 indium antimonide photodiodes is coupled to a silicon multiplexer, using hybrid fabrication techniques and resulting in low readout noise.

The device achieves the inherent high sensitivity of the diodes in an array format compatible with high-resolution imaging. It operates at temperatures from 55 to 80 kelvins (–360° to –315° Fahrenheit) and at readout rates up to 1 million samples a second. The line-array imager has been used in a laboratory demonstration and will be placed in a spectrometer for use at the 200-inch Hale telescope. The tests will confirm its performance capabilities in observing astronomical targets and will produce planetary infrared data previously unattainable.



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A. A three-dimensional reconstruction of a test artery based on ultrasound data.

B. An integrated, 128-element linear imager for the infrared region of the spectrum. The use of indium antimonide photodiodes makes possible readout rates of up to one million samples per second.

Tunable Lasers for Remote-Sensing Applications

Active laser sensing in the ultraviolet is an important measuring technique because it allows high spatial-resolution measurements of atmospheric properties by both day and night and complements traditional passive sensing methods.

Important advances in ultraviolet laser technology have been made at JPL under a NASA-sponsored laser development program for remote sensing.

A scanning, narrow-spectral bandwidth, ultraviolet xenon-chloride exciter oscillator-amplifier laser system has been developed. The system detects hydroxyl radicals produced in a combustion source by laser-excited fluorescence. The laser system is one-third the size of, and much less complex than, conventional dye-laser sources used for atmospheric measurements of species such as hydroxyl radicals, ozone, sulfur dioxide, and nitric oxide.

SPACECRAFT TECHNOLOGY

The Spacecraft Technology Development Program is directed toward higher-priority generic technologies with multimission applications. The goal is to demonstrate readiness to meet anticipated mission needs for large space systems, advanced Earth-orbital spacecraft, and advanced planetary spacecraft.

Sensor Cooling

During recent years there has been considerable growth in the use of spaceborne sensors that require cooling to maintain them at cryogenic temperatures; conventional passive radiators are not able to handle the required heat loads.

At JPL an effort has been made to solve the problem by developing an advanced passive radiator design. To improve its performance as a cooler, the advanced radiator uses new techniques to greatly reduce the parasitic radiative and conductive heat leaks from the hot spacecraft to the cold radiator.

A 68- by 40-centimeter (27- by 16-inch) thermal engineering model has been developed and tested in the 3- by 3-meter (10- by 10-foot) space-simulator chamber.

The test results and the analytical model indicate that the advanced radiator can be 50 percent smaller and lighter, have up to 50 times greater cooling capacity, and can achieve temperatures 30° or 40° Celsius lower than conventional passive coolers.

Automated Power-System Management

A demonstration of the feasibility of using microcomputer technology for automated operation of a spacecraft's electrical power system was completed in 1981. The demonstration used a Viking orbiter breadboard, which is representative of typical solar-array/battery-powered spacecraft power systems.

The technology provides the capability to implement onboard monitoring and fault detection and recovery without intervention from the ground. This eliminates the delay inherent in the long communications time lags of missions to the outer planets.

Accordingly, the need for ground support is significantly reduced, with a resulting reduction of costs and minimization of disruption in ground-station operations and communications.

This technology has been used at other NASA centers and is being incorporated into the JPL Autonomous Spacecraft Project for the Air Force Space Division.

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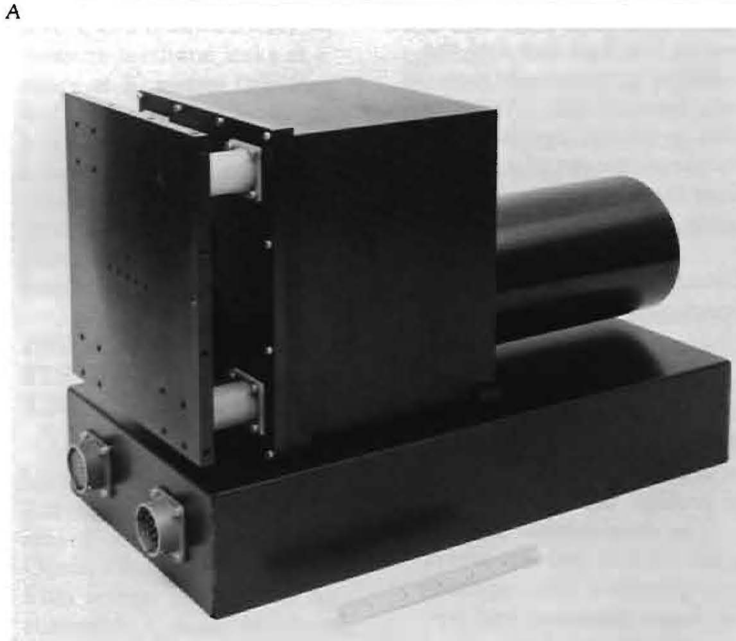

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Target-Body Tracker

Attitude control and science-instrument pointing by spacecraft have traditionally been Earth-based functions. As spacecraft probe farther from Earth the long delays in communication can threaten mission success.

JPL has developed a target-body tracker for onboard, automatic pointing control. The system's prototype became operational in 1981. The target-body tracker consists of a solid-state television camera connected to a microcomputer. It determines the position of stars, planets, satellites, other spacecraft, asteroids, and comets, thereby allowing the spacecraft's control system to correct for errors in navigation, predicted target position, and spacecraft attitude.

Heat-Sterilizable Solid Rocket Motor

A solid rocket motor capable of withstanding thermal sterilization has been developed and fired.

The goal was to produce a propellant system that would fire properly after withstanding seven heat cycles of 54 hours each at a temperature of 135° Celsius (275° Fahrenheit). A 272-kilogram (600-pound) solid-propellant motor was test-fired after passing the seven sterilization cycles.

The work followed the NASA requirement that any spacecraft designed to land on a planet must be biologically sterile.

TECHNOLOGY BRIEFS

The Laboratory undertakes technology development tasks to eliminate or minimize spacecraft subsystem performance problems, measure specific characteristics of the spacecraft environment, develop payload or payload-design approaches, and provide measurement and diagnostic instrumentation.

Contamination Monitor

A spacecraft contamination monitor aboard the NOAA-7 satellite, launched in June 1981, detected contamination induced by the firing of the apogee kick motor (AKM). AKM exhaust had been suspected of causing degradation of TIROS-N and NOAA-5 hydrazine thermal-control systems. Data indicate that significant amounts of contamination from both steady-state firing and the spent AKM were reflected from the back of the solar array after deployment, causing the thermal degradation. The findings of the experiment were the first direct evidence of the phenomenon.

Technology for Producing Fusion Targets

Inertial-confinement fusion is one of the promising techniques for future power generation. With this technique, spherical shells containing thermonuclear fuel are imploded by focusing intense bursts of beam energy on their surfaces.

The shells must be inexpensive, possess high sphericity, concentricity, and smoothness, and be able to contain internal pressures of up to 750 atmospheres.

A new technique for producing precision metal shells has been developed. Liquid metal is forced through an axisymmetric nozzle that contains a center tube providing a flow of fill gas. The resultant hollow jet flow of liquid is inherently unstable, causing it to pinch off spontaneously, thereby capturing the fill gas and forming shells.

A delay in freezing the metal causes the shells to

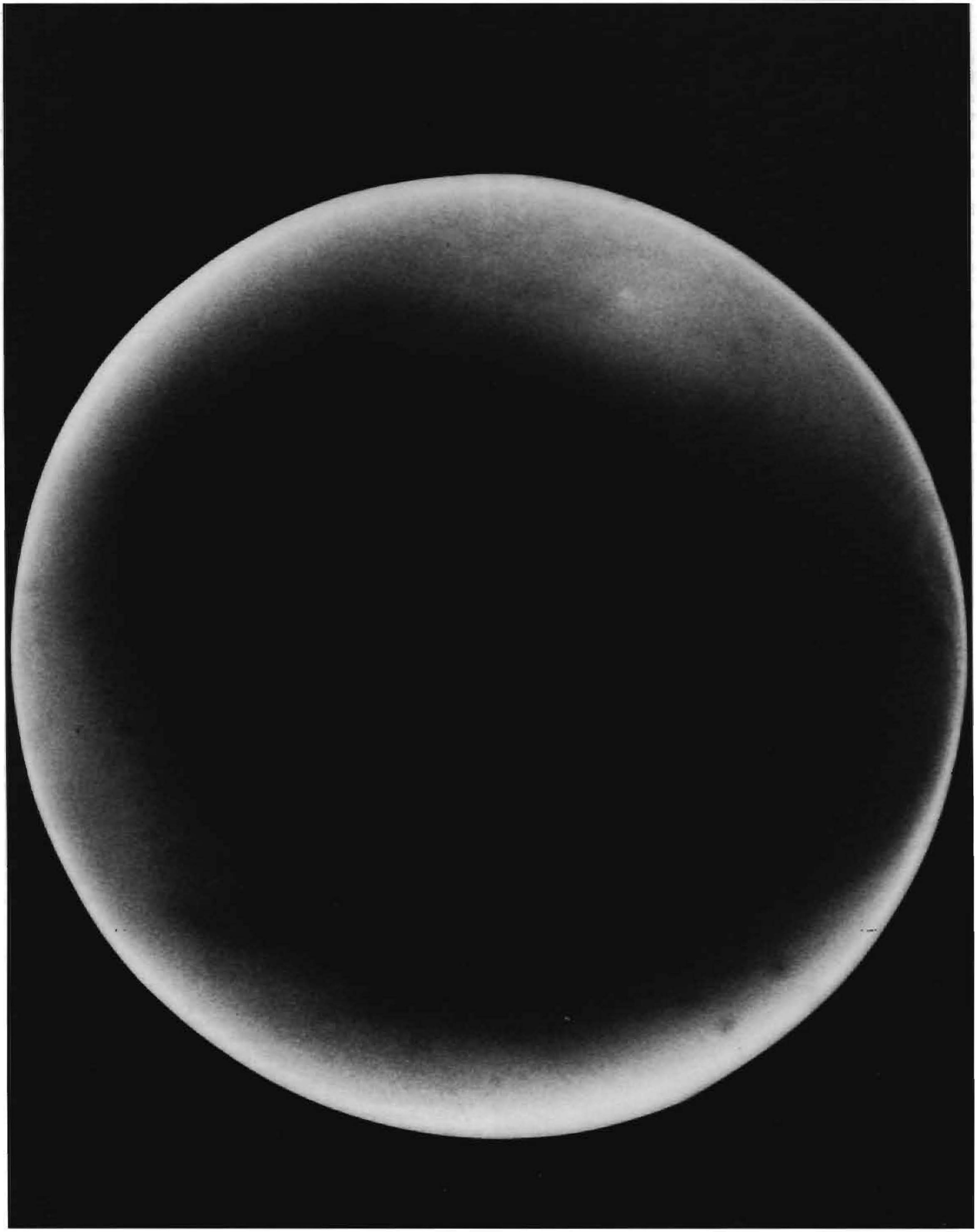
C

A. A novel arrangement of the JPL passive radiator includes highly specular and reflective lightweight radiation shields. The shields surround and actively isolate the cold, black radiating plate from the hot spacecraft environment.

B. The JPL target-body tracker has potential applications both in deep space and in hazardous areas on Earth. Unmanned probes for exploring deep oceans, mines, and active volcanoes are examples of terrestrial applications. Earth-orbital satellites, terrestrial- and outer-planet survey craft, interstellar probes, and robot landers represent possible deep-space applications.

C. A sterilized, solid-propellant rocket motor is test-fired. The test demonstrated JPL-developed technology for stabilizing propellant ingredients sufficiently to ensure their ballistic and physical-property integrity after thermal sterilization.

A



assume a spherical form of high precision and uniformity. The outer diameter is about 0.25 millimeter (0.01 inch) in present designs, but may be increased to 5.0 millimeters (0.20 inch) in later versions.

Efficient Diagnostics Through Acoustical Imaging

The concept of using acoustical imaging for local diagnostics of reacting and nonreacting flows was studied. An ellipsoidal acoustical-mirror microphone was designed, fabricated, and operated to map the local distribution of reaction rates along the length of a typical reaction zone and to detect charges due to changes in heat flux as reflected in the performance of a water boiler at the Edwards Test Station.

Picosecond Pulse Generation by Semiconductor Lasers

Investigation of the dynamics of semiconductor lasers at JPL has led to the development of techniques capable of generating by a direct pulsing approach 30-picosecond pulses at up to 2.5 gigahertz; 9-picosecond light pulses were observed by synchronously pumping, using short electrical pulses, a semiconductor laser mounted in an external cavity. The techniques, developed in collaboration with Chalmers University, Gothenburg, Sweden, will be applicable to ultra-high data-rate transmission in future optical information systems and in precise optical correlation radar for determining the shape of a large space structure.

Electromechanical Actuators

A new class of general-purpose electromechanical actuators has been developed, for the Galileo spacecraft, that deploy the high-gain antenna, deploy and point the probe-relay antenna, and activate a variable-spring-rate device in the spacecraft nutation-damping system.

The actuators provide two independent electromechanical drive trains that combine at a common output shaft. Both trains are continuously engaged and independently operable without common failure modes.

Analysis shows that a system containing parallel elements will be orders of magnitude more reliable than conventional redundant systems that contain one or more common functional elements.

The dual drive can be produced quickly and economically due to modular construction, manufacturing simplicity, and the use of commercial parts. It is expected that the actuators will find widespread applications on future space missions.

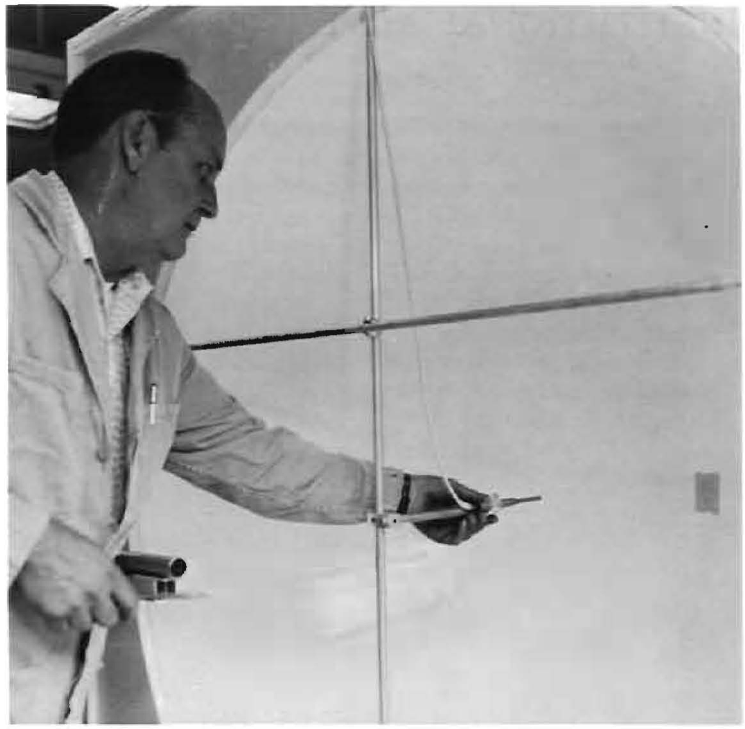
Land Mobile Satellite System

JPL and The Boeing Company performed a configuration study of a Land Mobile Satellite System spacecraft based on a preliminary system designed by JPL.

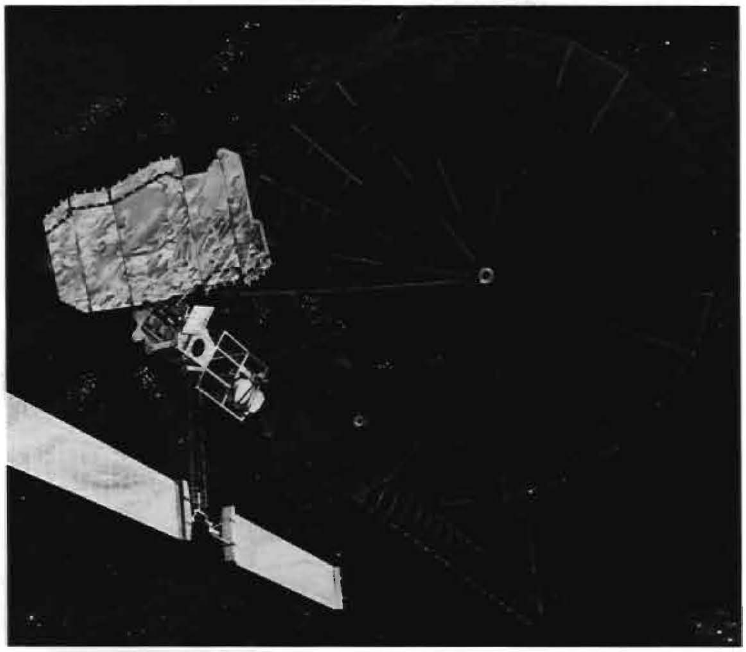
The spacecraft, in geostationary orbit, would relay radio messages to hundreds of thousands of land mobile units. Applications range from medical emergencies and disaster relief to law enforcement and truck dispatching. The satellite could also provide two-way mobile telephone channels in rural areas.

Mobile units would communicate via the satellite to base stations serving as the interface to the telephone network.

The 4,000-kilogram (8,800-pound) spacecraft would be launched from the Space Shuttle and would have a 10-year lifetime, beginning in the mid-1990s.



B

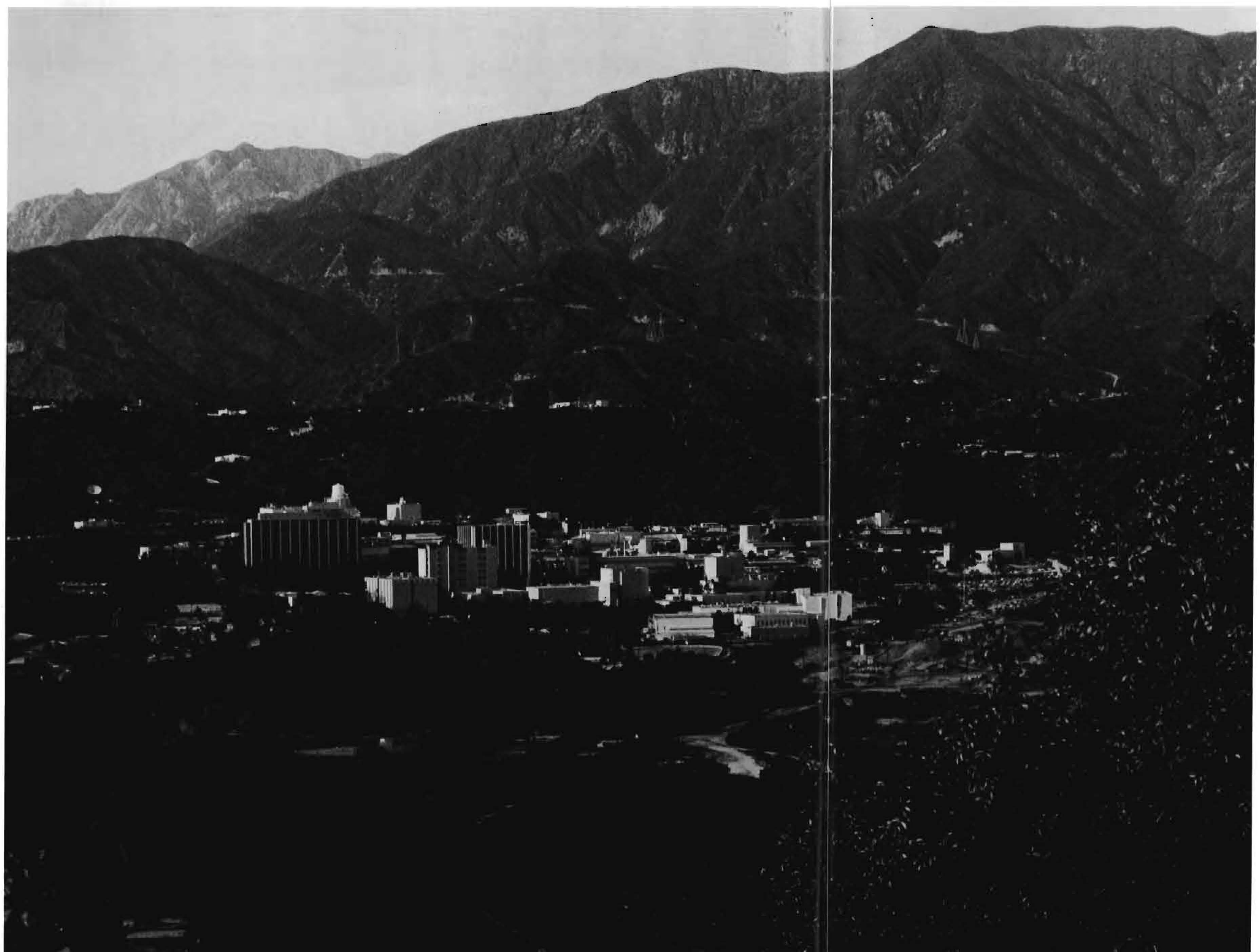


C

A. Radiograph of a hollow-sphere fusion target. This shell, measuring 2.0 millimeters (0.08 inch) in diameter, was formed of tin.

B. The ellipsoidal acoustical-mirror microphone designed and fabricated by JPL as part of the Solar Thermal Fuels and Chemicals Project.

C. A preliminary configuration of the Land Mobile Satellite System Spacecraft. The parabolic antenna, which stretches 55 meters (182 feet) in diameter, dominates the structure.



In 1980 three executive committees were established to address and coordinate the increasingly numerous and complex crosscutting issues faced by the Laboratory. Serving as adjuncts to the Executive Council, the three committees cover solar system exploration (SSEEC), utilitarian programs (UPEC), and institutional matters (IEC) and are chaired by, respectively, Bob Parks, Bud Schurmeier, and Fred Felberg.

This year the Director has taken the step of bringing the three executive-committee chairmen into the Director's Office as associate directors of the Laboratory. Each will take on as a full-time responsibility the area represented by his existing executive committee, which will continue to function.

The SSEEC provides management overview and coordination of JPL activities in space science and exploration, including extra-solar-system investigations using instruments located on or above Earth, and Earth observations from space.

The UPEC provides management guidance and coordination of utilitarian programs, including defense, energy, and such technology applications as biomedical engineering.

The IEC is responsible for overview, coordination, and integration of planning and control activities in institutional matters affecting more than one program or organizational area.

DEFENSE PROGRAMS OFFICE

The past year was a time of considerable uncertainty for NASA's planetary program and for the Laboratory, due to restrictions on the NASA budget. To help keep the Laboratory a viable, working institution, a major effort has been mounted to seek substantial additional research work from the Department of Defense.

At the beginning of fiscal year 1981, this new program office was formed to serve as a focal point for the acquisition and management of all DOD work at JPL.

Currently funded defense-program efforts range from large projects, for which JPL has full project-management accountability, to smaller advanced-technology tasks that draw from the broad technology base at JPL.

OFFICE OF ENGINEERING AND REVIEW

Functions of the Office of Engineering and Review were reoriented to emphasize the importance of sustaining high quality in all aspects of the Laboratory's work.

The Office of Planning and Review was renamed on June 22, 1981, as the Office of Engineering and Review. Its primary responsibility is quality assurance and reliability. The office also emphasizes effective review processes and the evaluation of program-related engineering policies and standards.

Two major functions were transferred from other organizations to the Quality Assurance and Reliability Office: environmental requirements and testing and electronic parts engineering, testing, and failure analysis. The transfer was done to focus those and other program-assurance activities within the Office of Engineering and Review.

During fiscal year 1981, 28 formal reviews were conducted, 12 for the Flight Projects Office, five for the Telecommunications and Data Acquisition Office, six for the Energy and Technology Applications Office, four for the Defense Programs Office, and one for the Technology and Space Program Development Office.

PATENTS AND TECHNOLOGY UTILIZATION

The Office of Patents and Technology Utilization evaluates, patents, and helps NASA publicize the many inventions and technological innovations resulting from JPL work. In 1981, 272 inventions and innovations were disclosed to NASA and other sponsors of JPL.

The U.S. Patent Office issued 41 patents to Caltech and NASA for JPL inventions. The office also helped NASA and Caltech identify potential licensees who had an interest in NASA- or Caltech-held patents, issued or pending. Caltech's record of licensing more than one-third of its patented JPL inventions was maintained.

The office provided information on 89 JPL inventions and innovations reported in NASA's *Tech Brief Quarterly*, and mailed technical-information documents in response to more than 24,000 inquiries about JPL inventions.

VISITING SCIENTISTS

A Distinguished Visiting Scientist Program, initiated by the Director in 1979, continued to provide eminent authorities for short-term consultation on important JPL projects.

The distinguished visiting scientists are Professors Klaus Hasselmann, Germany; Jacques Blamont, France; Michael S. Longuet-Higgins, England; Giuseppe Colombo, Italy; and Peter Niiler, Eugene Shoemaker, Richard Goody, and Klaus Keil of the United States.

Under a Faculty Fellowship Plan sponsored by NASA, DOE, and the American Society for Engineering Education, 35 other professors from U.S. campuses spent the summer in residence. They made significant contributions to JPL projects and carried valuable practical experience back to their students.

CALTECH PRESIDENT'S FUND

The NASA–Caltech Memorandum of Understanding provides for the President's Fund, which funds collaborative efforts between JPL staff and faculty and students from Caltech and other universities.

NASA contributes up to $350,000 a year to the Fund on a matching basis. There are now about 35 active tasks. Besides Caltech, the schools involved include the University of Arizona, the University of Chicago, the University of Southern California, Penn State University, Duke University, Cornell University, Stanford University, the University of Minnesota, and four campuses of the University of California.

DIRECTOR'S DISCRETIONARY FUND

The Director's Discretionary Fund (DDF) was established in 1969 as part of the NASA–Caltech Memorandum of Understanding.

The objective is to provide funds for independent research and development in promising fields of science and engineering, emphasizing innovative and seed efforts and encouraging collaborative work with faculty and students at Caltech and other universities. The potential for follow-on funding from other sources is one criterion in selecting tasks for DDF support. The Fund is at a level of $1 million a year.

The response to the annual solicitation for proposals is enthusiastic, resulting typically in about 100 proposals corresponding to a dollar value exceeding the resources available by a factor of four or five. Twenty-nine new tasks were initiated with fiscal year 1981 funds, including a number that, although worthy of encouragement, could be supported only at significantly lower levels than requested.

SPECIAL RECOGNITION

JPL employees and activities received these awards during 1981:

Voyager Project Team

The Team received the Robert H. Goddard Memorial Trophy, sponsored by the National Space Club This was the second consecutive year that Voyager won the award

The Team also received the Robert H Collier Trophy, sponsored by the National Aeronautic Association.

Raymond L. Heacock, Harris M. Schurmeier, John R. Casani

Each received the Astronautics Engineer Award sponsored by the National Space Club

Bruce C. Murray

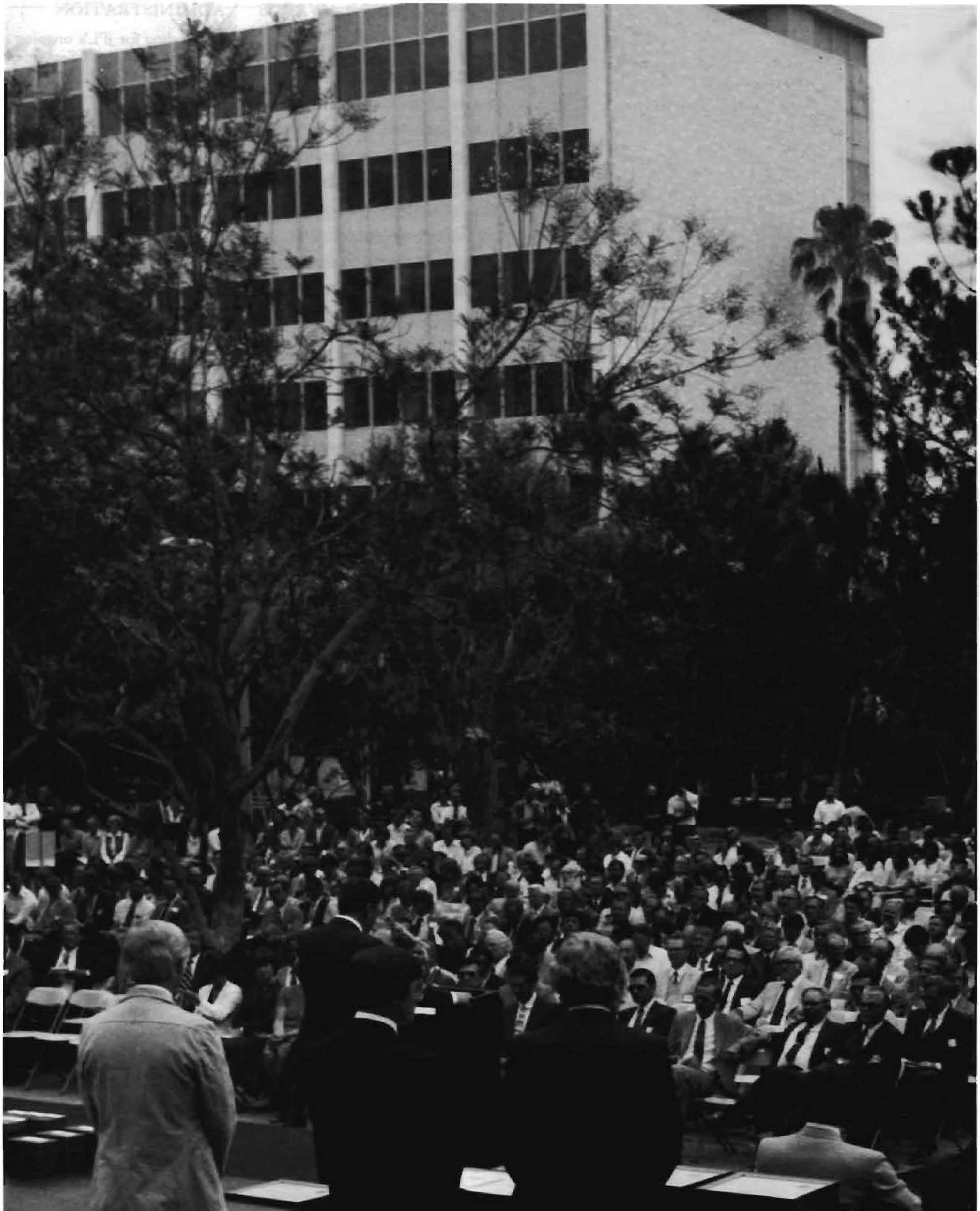
The Director was selected by the American Institute of Aeronautics and Astronautics to deliver the Von Karman Lecture in Astronautics.

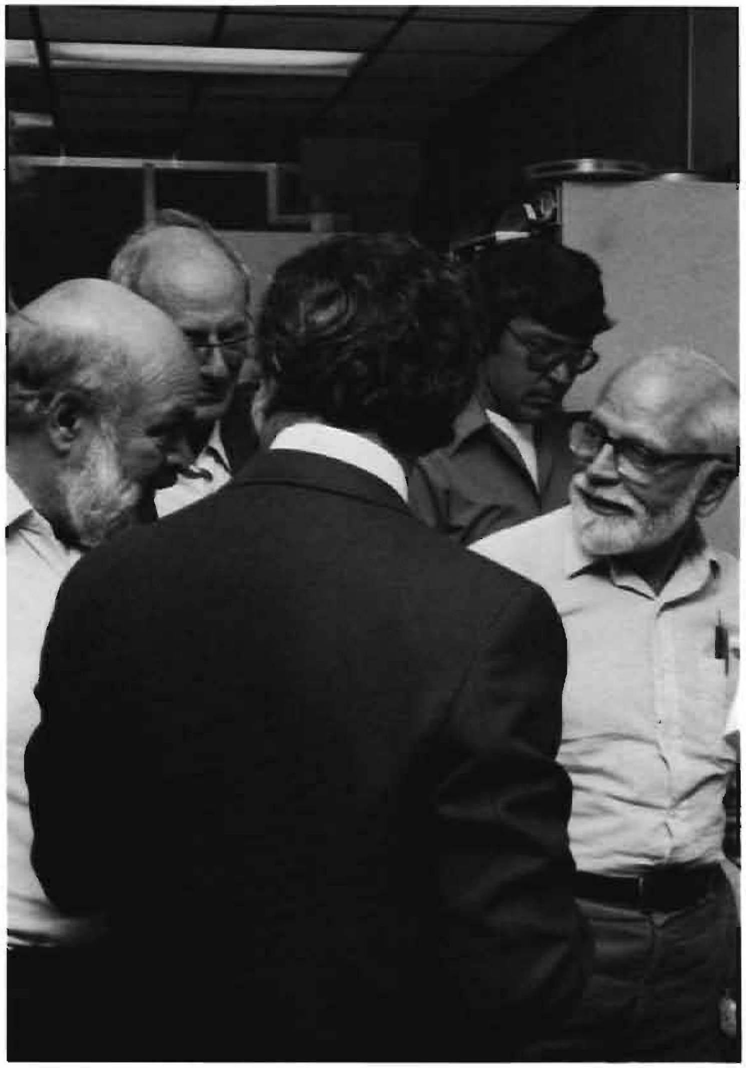
John W. Armstrong

He was selected as an outstanding young radio scientist by the National Academy of Sciences and was named the Henry G. Booker Fellow

Richard M. Goldstein, Warren L. Martin

The pair shared a $10,000 cash award from NASA for the development of a spacecraft ranging system named the Binary Coded Sequential Acquisition Ranging System.





NASA HONOR AWARDS

The NASA Annual Honor Awards program provided special recognition of outstanding individual and team efforts:

NASA Exceptional Scientific Achievement Medal
William R. Ward and Richard C. Willson

NASA Exceptional Engineering Achievement Medal
Robert F. Fedors and Peter F. MacDoran

NASA Exceptional Service Medal
Joseph G. Bastow, Jr., Harold R. Donnelly, Ronald G. Ross, Jr., and Chialin Wu

NASA Public Service Medal
Donald R. Fowler (California Institute of Technology)

NASA Equal Opportunity Medal
Robert Ibaven

NASA Group Achievement Award
The Basic Noise Research Team, the Energy Reduction Task Force, the Seasat SAR Digital Processor Development Team, and the 34-Meter S-X Tracking Antenna Project Implementation Team.

VOYAGER PROJECT AWARDS

The NASA Honor Awards Program in 1981 also recognized many groups and individuals who have participated in the Voyager Project. The members are too many to list here, but from the JPL staff alone included 68 recipients of Exceptional Scientific Achievement Medals and 17 recipients of Outstanding Leadership Medals. Distinguished Service Medals were awarded to Raymond L. Heacock, Bruce C. Murray, and Harris M. Schurmeier.

ADMINISTRATION

Funding for JPL's ongoing and new tasks as of September 30, 1981, amounted to $309,274,795 for NASA programmatic tasks, $4,769,790 for NASA nonprogrammatic tasks, and $85,973,876 for tasks from non-NASA sponsors.

The combined total ($400,018,461) represents an increase of 2.75 percent over fiscal year 1980 funding of $389,276,151.

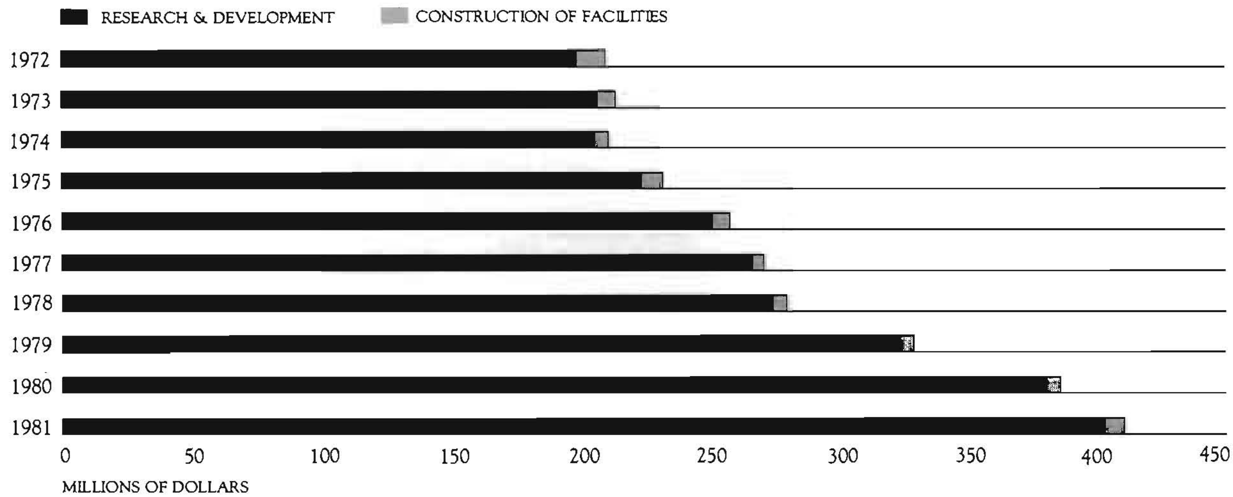
Procurement obligations of $191,778,000 were 14 percent lower than in fiscal year 1980, primarily reflecting reduced procurement for NASA programs. Small Business transactions decreased by 13 percent to $55,316,000 while transactions with minority-owned businesses increased to $7,716,000, a gain of 6 percent over the prior year.

Despite a slight decrease (1.3 percent) in JPL's work force during the year, the representation of minorities and women showed modest increases of 0.2 and 1.4 percent respectively.

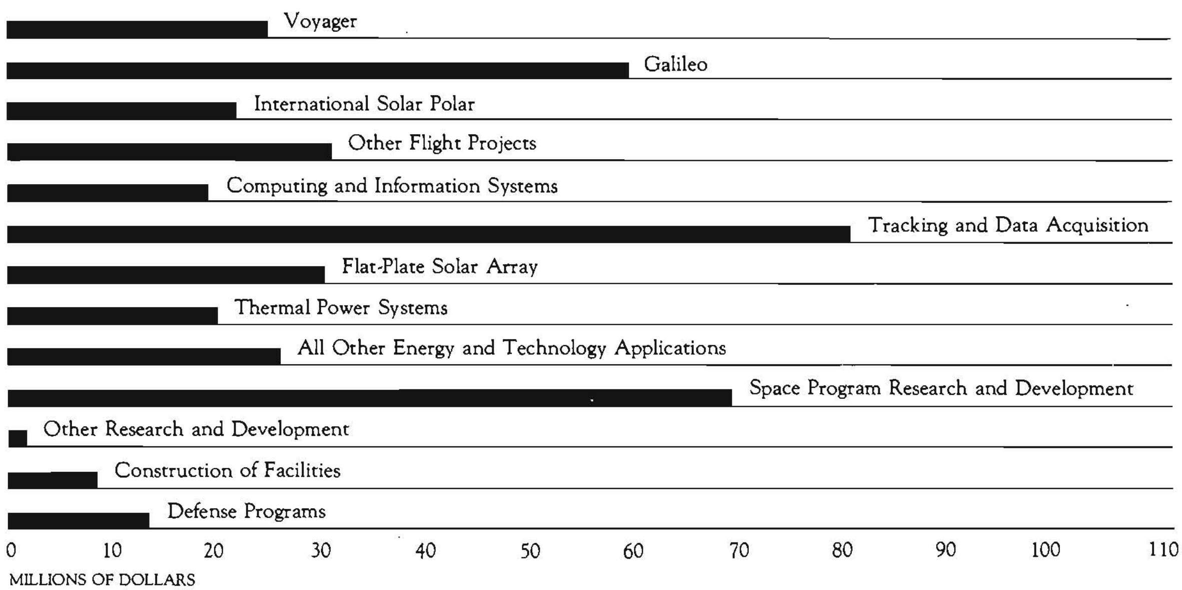
JPL continued as a leader in NASA's energy-conservation program. The JPL Energy-Reduction Task Force was awarded the NASA Group Achievement Award. JPL was also recognized with a major award from the Southern California Gas Company. Through the end of fiscal year 1981, JPL's annual energy consumption remained 39 percent below the baseline consumption in 1973, despite high summer temperatures and Voyager encounter activity.

TOTAL COSTS

FISCAL YEARS

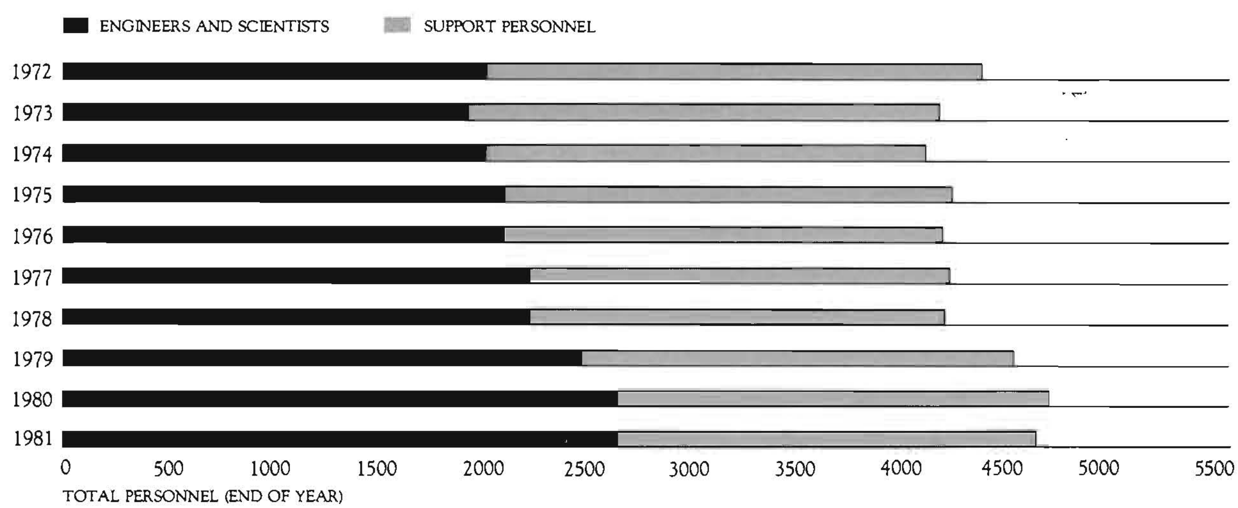


FISCAL YEAR 1981 COSTS



PERSONNEL

FISCAL YEARS



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